VIEWPOINT

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The evolution of the U.S. Farm Bill

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ABSTRACT

The enabling of a US Farm Bill affects not only American farmers, but producers and consumers across the world. The passage of the current farm bill has been marked by unusually contentious political infighting resulting in significant delay and, at the time of writing, uncertainty about the outcome. The author predicts 'stark changes' for US producers, with a drastically reduced safety net should market prices fall.

KEYWORDS: US Farm Bill; agricultural policy; commodity program; safety net

In the U.S., the Congress establishes agricultural and food policy in an omnibus farm bill. The current farm bill was passed in 2008 and was scheduled to end in 2012. When the Congress failed to pass a new comprehensive bill, the 2012 Farm Bill was extended one year. Over time, farm bills have had differing lengths but in recent years have generally been for five years. While called a farm bill, the legislation spans all facets of agriculture from commodity programs that support farmers to forestry, credit provisions, renewable energy, crop insurance to the largest component in terms of outlays - nutrition programs to help those who would otherwise do without. The components of the bill are arranged in titles much like we refer to chapters of a book.

One of the nuances of any farm bill is the amount of money available to be spent on the next bill is determined by how much would have been spent if the expiring bill were continued. Table 1 presents the current policy (2008 Farm Bill) baseline for the 2014 to 2023 period. Roughly 80 percent of expenditures are for nutrition programs. What is striking about this table is there are 15 titles in the 2008 Farm Bill but the amounts are significant for only four (Nutrition, Commodity Programs, Conservation, and Crop Insurance). Annual commodity program expenditures include the \$5 billion[3] per year decoupled direct payments that farmers receive regardless of prices or whether they produced anything and a small amount (<\$1 billion) of support based on expected low prices for a few crops (peanuts and rice). To provide some perspective on the relative size of the commodity program expenditures, the U.S. routinely spent around \$10 to 12 billion per year over the past two decades with a high of nearly \$30 billion per year during the farm crisis of the 1980s.

U.S. Farm Bill Development

The process of developing a farm bill in the U.S. starts roughly 2 years before the current bill is to expire. The House and Senate hold hearings in key agricultural regions and in Washington D.C. designed to solicit suggestions for improvements. For example, the House of Representatives conducted over 30 hearings in which farmers, commodity groups, agribusiness groups, lenders, academics and others were called upon to provide their perspective and suggestions for needed adjustments in U.S. agricultural policy.

The process is supposed to end with the House and Senate each passing a farm bill that would then be conferenced by a small group of members from each Chamber. The resulting bill would be presented to members of each Chamber for a yes or no vote without amendment. If it passes each Chamber then it is sent to the President to be signed into law. The current process has been anything but routine. For the first time in the 80 year history of omnibus farm bills, the group of legislators who initially brought up the bill (112th Congress) failed to pass a bill they brought up and left it for the current (113th Congress). In addition, the House recently passed a version without the Nutrition title while the Senate has passed a version with all the normal titles.

Factors Contributing to the Delay in Farm Bill Passage

There isn't one factor that can be attributed to the lack of a farm bill. The following are a few of the widely cited reasons for the delay:

- Perception among many in Congress that recent high prices for *some* commodities has lessened the need for a farmer safety net. This is especially important considering deficit reduction efforts that began in 2012 championed primarily by the Republican party.
- Moderates of both parties have lost in recent elections. The influence of the extreme right of the Republican party and extreme left of Democratic party has made compromise almost impossible. As an example, many new Republican members of the House voted against the House Bill because it was

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[2] This paper appeared in an earlier form to support a keynote address to the 19th International Farm Management Congress in Warsaw, Poland, July 2013.
[3] In early September 2013, \$US 1bn was approximately equivalent to £642m and €759m (www.xe.com)

Table 1: Mandatory Spending Baseline for the 2008 Farm Bill Programs and Provisions, by Title, ($USm), Fiscal Years 2014-23

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
I Commodity Programs (CCC)	5,898	6,750	7,141	6,557	6,325	6,306	6,300	6,343	6,298	6,366
II Conservation	5,568	5,564	5,843	6,086	6,427	6,690	7,033	6,810	6,838	7,098
III Trade (CCC)	344	344	344	344	344	344	344	344	344	344
IV Nutrition	79,672	79,091	79,106	77,816	76,368	75,125	74,124	73,384	72,928	72,928
V Credit	-100	-169	-174	-181	-187	-194	-201	-208	-216	-220
VI Rural Development	10	3	0	0	0	0	0	0	0	0
VII Research and Related Matters	93	18	0	0	0	0	0	0	0	0
VIII Forestry	2	1	0	0	0	0	0	0	0	0
IX Energy	8	5	21	23	27	27	30	32	35	35
X Horticulture and Organic Agriculture	116	105	105	105	105	105	105	105	105	105
XI Livestock	0	0	0	0	0	0	0	0	0	0
XII Crop Insurance and Disaster Assistance	6,955	8,279	8,216	8,274	8,383	8,540	8,781	8,931	9,052	9,165
XIII Commodity Futures	0	0	0	0	0	0	0	0	0	0
XIV Miscellaneous 6/	0	0	0	0	0	0	0	0	0	0
XV Trade and Tax Provisions	---	---	---	---	---	---	---	---	---	---

projected to only save $30 Billion over 10 years–they wanted more cuts.

- Lack of agreement/backstabbing among commodity groups regarding commodity program. Generally the groups come together to coalesce around a single plan. That has not happened.
- Small, generally conservative interest groups have attacked the farm bill by threatening to provide a poor effectiveness rating to any members voting for the bill.

What are the differences in the Senate and House Commodity Provisions?

The bills are very similar except for some key elements of commodity programs. The Senate bill puts all crops other than cotton in the Agriculture Risk Coverage (ARC) program. ARC is a shallow loss type of safety net program that provides a small amount of a producer's historical revenue in the event of a loss. Coverage is up to a maximum of 10% of a producers 5 year Olympic average of revenues for the crop. Adverse Market Payments (AMP) are also provided which are intended to protect farmers if prices fall below 55% of the 5 year Olympic average of market prices.

The House of Representatives also contains a shallow-loss program (Revenue Loss Coverage - RLC) and a deeper price loss coverage (PLC) program similar to the AMP program in the Senate but the PLC program has higher price triggers.

In general, the Senate has made the ARC program the better option for producers while the PLC option provides the most complete support in the House version. Both shift commodity program funding to a new supplemental coverage option (SCO). This is an area-wide insurance program is available for purchase to cover shallow losses on top of current buy-up insurance.

The reality is there will be stark changes for U.S. producers to deal with in the next farm bill because the decoupled direct payment totalling $5 billion per year is eliminated in both the House and Senate farm bills. The direct payment provided U.S. producers a certain amount of money each year–guaranteed. But more importantly, lenders received the certainty of getting a large portion of the money they loan a producer back. The producer safety net without direct payments is significantly weakened. At current expected prices, the adjustments will be minimal. However, if prices were to fall to levels that some predict over the next few years U.S. producer will have much less of a government safety net than before.

About the author

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REFEREED ARTICLE

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Defining foresight activities and future strategies in farm management: empirical results from Finnish FADN farms

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ABSTRACT

Increasing farm sizes, stronger market orientation and meeting consumers' expectations call for managerial skills and stronger future orientation in farm businesses. We scrutinise in this paper what kind of future goals and foresight approaches farm management entails. As part of strategic management, we approached planning practices according to their time-scale. Three managerial and foresight dimensions of future orientation were defined based on literature; they were then used when constructing a questionnaire. Data were gathered from two sources: from a farm survey and from the annually gathered Farm Accountancy Data Network (FADN) database in Finland between 2004 and 2008. The farm survey data were analysed through factor analysis and *k*-means cluster analysis. According to our analysis, farms were grouped into three future-oriented farm groups. The FADN data also gave an opportunity to examine economic and structural development in the defined farm groups. According to our results, the three farm groups differ from each other in terms of future orientation and in terms of structural and economic development.

KEYWORDS: farm management; future goals; foresight; economic and structural development

1. Introduction

Management is a continuous process of future thinking, planning, implementation and control. Strategic management has been defined as the process of planning, implementing and controlling decisions for a common goal by different units or functions of an organisation. This enables the organisation to define and achieve its mission to create value (Porth, 2003; David, 2005; Mintzberg, Ahlstrand and Lampel, 1998). Increasing farm sizes and significance of managerial skills entail value-adding management models, strategic tools and building managerial competence within farms. The last of them, i.e. managerial competence, has gained a lot of attention. This is due to farms investing in growth especially in animal production and the Common Agricultural Policy (CAP) continuing to undergo reforms towards greater market orientation in the European Union. Therefore, the need for anticipating future changes and their impacts on farm production is increasing. In farm businesses today, farmers should more and more recognise, in addition to the production itself, the possibilities and threats of market changes, technological development, policy changes, and changes in consumer behaviour, at the least. According to Micheels and Gow (2011) in the case of the beef sector, high market orientation benefits farms in value creation. Therefore, more than before, a farmer is also supposed to take into account the farm business logics (i.e. value creation, cost structure, revenue streams) in parallel with production processes and technologies. Also consumer expectations towards agricultural products and by which principles they are produced require communicative preparedness of farmers.

Strategic planning is the cornerstone of strategic management. It is used in setting priorities, allocating energy and resources, strengthening operations and ensuring that employees work toward common goals (Bryson 2003). A shortcoming of conventional strategic planning is its lack of sensitivity in coping with changing environments and managing weak signals and turbulence (Camillus and Datta, 1991). Strategic planning is often confused with forecasting (Armstrong, 2001). Planning concerns about what the world should look like, while forecasting is about what it will look like. Martino (1983) defined forecasting as calculating or predicting some future event or condition usually as

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a result of rational study and analysis of available pertinent data.

The main idea behind foresight methods is that there is not just one single possible future but many different futures. The main principle is that the one future which will materialise cannot be predicted. The future, as it comes, consists elements from all alternative, imaginable scenarios. From the strategic planning point of view, foresight tools are used in becoming aware of all different possibilities and future developments. Therefore, one can be better prepared for surprising events and set strategic goals and measures (McMaster, 1996; Cuhls, 2003; Rikkonen, 2005). For example, scenario methods as one of the approaches in future studies methodology are claimed to support strategic decision-makers (van der Heijden, 1996). They are especially effective in addressing uncertainties as they explain the alternative, both desirable and undesirable or even probable paths of future development (Postma and Liebl, 2005; Rikkonen 2005). Also, predicting the future just by looking into the past can lead to wrong decisions when conditions are changing rapidly and adaptively.

The concepts of strategic management and visionary leadership have been combined more and more in the discussion of the art of strategic thinking (Westley and Mintzberg, 1989). According to Rampersad (2001), visionary management is a key issue for all organisations. It is a continuous rethinking toward future and competitive advantage. By making visionary thinking a part of daily routine, it will integrate into all aspects of work. Farm management in this respect does not differ from other branches of business. Increasing farm sizes and significance of managerial skills also require future orientation in farm business like in any other branch of business.

In this paper, we scrutinise three important aspects of future orientation in farm management, namely future goals, planning horizon and foresight approach. This is done to define the role and meaning of foresight activities in farm management and to examine differences which farms of different approaches may have in their economic and structural development. We study the management of a farm enterprise from operational, strategic and visionary time perspectives. Therefore, this study proposes new insights and ideas for the long-range planning of a farm. The results benefit farm enterprises in achieving a better and comprehensive management level with operational, strategic and visionary perspectives.

The approaches to future management are presented in Figure 1. Operational management refers to the planning practices of less than one year utilising the competence of a farm to react to the current situation in the best possible way. Strategic management is used when preparing for changes in the operational environment and allocating farm resources efficiently in the perspective of more than one year but less than five years. Visionary management as a part of strategic management refers to a time frame of more than five years in planning practices and it prepares the farm for future uncertainties. Visionary management adds to strategic planning as it also includes different foresight tools and activities to be utilised. For example, Porter (1985) sees that scenarios are another tool in the strategist's arsenal that helps decision making. According to Wilson (1992), vision is a coherent and powerful statement of what the business can and should be for example in ten years' time. It also defines the most important future core competencies. This research examines especially the need for advanced strategic thinking (see e.g. Holstius and Malaska, 2004) defined as visionary management.

The structure of the article is the following. First, we make the attempt to define various dimensions which one has to consider when expanding the management focus into a longer, visionary time frame in farm enterprises. We present important dimensions found in foresight literature which were used as a basis for questionnaire construction. Second, we present the formulation of the conducted survey and the way how we utilised the survey data with the FADN farm data. Third, we present the analysis methods used in classifying the farms in order to describe the characteristics of the farm groups according to their future orientation. Fourth, we present the results and compare farm groups with economic and structural indicators to pinpoint the differences and similarities in farm groups. Finally, the discussion and conclusions follow.

The specific research questions in this paper are:

(1) What kind of future goals do farmers have for their farm enterprises?
(2) Do these different future goals reveal the use of different planning horizons or a different foresight approach in farm management (from operative to visionary horizon and from a passive to a proactive approach)?
(3) What is the link between the future goals used and the success of the farm as measured by economic and structural indicators (e.g. profitability, growth)?

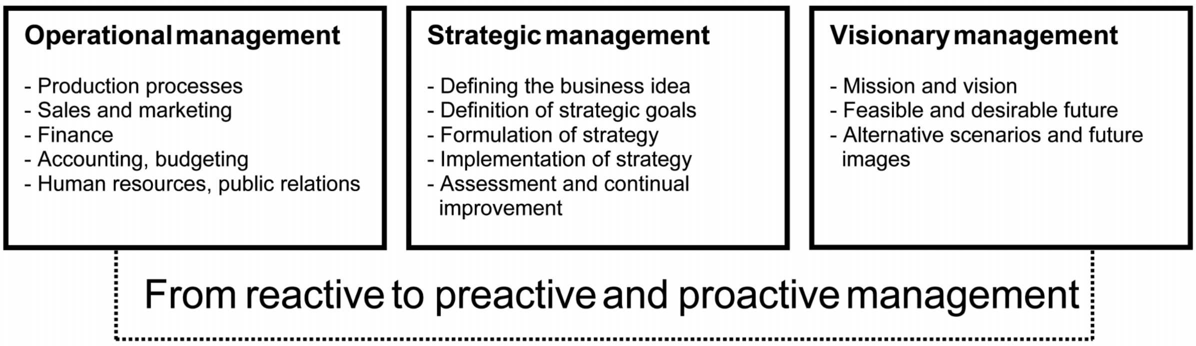

Figure 1: Management of a successful farm enterprise (applied from Malaska and Holstius, 1999; Holstius and Malaska, 2004)

2. Material and methods

First, we looked into the available, mostly referenced literature of strategic and visionary management and of futures studies. According to the literature review, three important dimensions were defined and then used as a basis for questionnaire construction. These measuring dimensions in defining the level of future orientation on farms were: 1) future goals of farm enterprise 2) time horizon of foresight (operational, strategic, visionary) and 3) a foresight approach (passive, reactive, preactive and proactive). According to Godet and Roubelat (1996), the passive approach means that changes in operational environment do not affect the plans of an organisation or an entrepreneur or cause any actions. The reactive approach is simply reacting to ongoing changes after they have happened. The preactive approach means that changes and alternative future paths or scenarios are anticipated actively and they are influential in strategic plans. The proactive planning involves designing or even provoking desired future and then inventing ways to create that future state. The purposes of conducting a survey of these three dimensions were, first, to define what kinds of alternative future strategies farms have and, second, what kind of foresight approach Finnish farms have overall.

After questionnaire construction and testing, a mail survey was conducted in 2007. The respondent farmers were inquired about the above defined dimensions of foresight approaches and future goals. The questions used in the analysis of this study included the following (they were asked in Finnish and translated into English for this paper):

Q1. How important do you think the following long-term future goals are on your farm? (The respondents used the Likert scale from 1 to 5 [1=not important at all, 5=very important].)

a) Good profitability
b) Continuing growth
c) Rationalisation of production
d) Good liquidity and sufficiency in income financing
e) Reasonable subsistence
f) Mental satisfaction of being a farmer
g) Taking care of the environment
h) Developing professional skills
i) Continuity of family farm
j) Preparation to give up farming

Q2. How do the following statements describe your future planning? (The respondents used the Likert scale from 1 to 5 [1=not at all, 5=very well].)

a) Changes occurred in operational environment do not affect our plans.
b) We react to ongoing changes on a continuing basis.
c) We anticipate changes actively and they act as impulses in our production and business plans.
d) We continuously work for creating our desired future and invent ways to influence future development in our network and our operational environment.
e) We concentrate on planning our farm business on a one-year planning basis.
f) We continuously plan our business operations in a 3 to 5 year time perspective.
g) We have created a shared vision on where we want to be within 10 years (desired future state of operational environment in ten years' time).

Q3. As an entrepreneur, I seek new information which can affect the production and business of my farm from the following sources: (The respondents used the Likert scale from 1 to 5 [1=not at all, 5=very actively].)

a) From local-level media, networks and professional sources etc.
b) From national-level media, networks and professional sources etc.
c) From EU-level media, networks and professional sources etc.
d) From global-level media, networks and professional sources etc.

Alongside the conducted farm survey (valid n=260 farms), Farm Accountancy Data Network (FADN) data from the same farms were obtained to scrutinise economic and structural changes in defined farm groups during the five year period 2004–2008. The data for examining the economic and structural changes between farms are based on the annually gathered FADN database from Finland concerning the years 2004–2008. The FADN system contains a sample of over 1,000 farms, and the database is maintained by MTT Agrifood Research Finland, Economic Research. We started to use the FADN data were after the farm survey analysis was done.

The analysis to classify the farms was based on the questions about the above-mentioned long-term future goals of farms. The purpose of inquiring about these goals was to have an overview of varying future goals and, thus, to analyse if it is possible to construct different farm groups. This analysis was then followed by evaluating how the economic and structural development differs when the future goals are different.

The data analysis was mainly performed by two statistical methods, factor analysis and cluster analysis. The statistical runs were done using IBM SPSS Statistics 19 software. Factor analysis is a statistical procedure used to uncover relationships among variables. It allows numerous intercorrelated variables to be condensed into fewer dimensions called factors. The method has traditionally been used to provide mathematical models for the explanation of psychological theories of human ability and behaviour (Harman, 1976). Applications of factor analysis have then become popular also in other fields of science, such as economics, political sciences, sociology, and medicine. Factor analysis, like all statistics, is a branch of applied mathematics. Thus, it is used as a tool in the empirical sciences (Harman, 1976). In the context of this study, the variables are the subjectively stated future goals on the Likert scale from one to five. The generated factors represent the general future goal dimensions of each farm groups.

The used factor analysis is beneficial, because it allows the studied variables to be condensed into fewer dimensions (i.e. factors). For the purposes of this study the factor analysis was not enough, because the aim was also to further classify farms of different types. Therefore, classification by cluster analysis was a useful way to further analyse the data. In this study, the cluster analysis was used because it allowed categorising similar

Table 1: Rotated factor matrix

Long-term goals of farm enterprises	Factor		
	1	2	3
Good profitability	.389	**.549**	.039
Continuing growth	**.597**	.073	.035
Rationalisation of production	**.610**	.268	.016
Good liquidity and sufficiency in income financing	.152	**.593**	.173
Reasonable subsistence	.039	**.600**	.153
Mental satisfaction of being a farmer	.026	.262	**.595**
Taking care of the environment	.146	.050	**.647**
Developing professional skills	**.471**	.233	.419
Continuity of family farm	**.489**	.038	.215

Extraction method: Principal axis factoring
Rotation method: Varimax with Kaiser normalisation
a. Rotation converged in 6 iterations

farms in clusters. Cluster analysis is a collection of statistical methods which identifies groups of samples behaving similarly or showing similar characteristics. The simplest mechanism is to partition the samples using measurements which capture similarity or distance between samples (Romesburg, 1984).

3. Results

As a result of the factor analysis, three factors were identified and extracted from the future goals asked in the survey (Table 1). One of the future goal questions ('preparation to give up farming') was discarded due to a low communality (value was 0.1). Other options were also tried during factoring. For example, when constructing the farm groups, it was found that a four-factor solution was also possible, but it was less logical in terms of balanced future goal dimensions of farms. This was because in the four-factor solution there was one factor which carried a large loading by only one variable. This variable measured the goal of developing competence and it suited well for the three-factor solution. To evaluate the alternative analysis paths, the cluster analysis (*k*-means) was done based on this four-factor solution. It resulted in four groups in which one group is relatively small. Also, the eigenvalue was decisive in factoring. Only those factors were included in which the eigenvalue was over 1.0. In the factor analysis, the extraction method applied was principal axis factoring and the rotation method used was Varimax rotation with Kaiser normalisation.

For the purposes of *k*-means cluster analysis, factor scores were first calculated and then treated as new variables in the cluster analysis. In the three-cluster solution, the clusters included 59, 134 and 67 farms (Table 2). In the four-cluster solution, there was one cluster consisting of only 39 farms. Therefore, the three-cluster solution remained.

According to the factor analysis, the farms were then organised into three farm groups: 1) traditional and environmentally oriented farms, 2) economic success oriented farms and 3) growth and development oriented

Table 2: Final cluster centres

	Cluster		
	1	2	3
REGR factor score 1 for analysis 1 'Growth orientation'	−.95576	.28736	.26693
REGR factor score 2 for analysis 1 'Economic orientation'	−.62948	.44976	−.34519
REGR factor score 3 for analysis 1 'Environmental and wellbeing orientation'	.05252	.39899	−.84423

Number of observations in clusters		
Cluster	1	59
	2	134
	3	67
Valid n		260

Test results	REGR factor score 1 for analysis 1	REGR factor score 2 for analysis 1	REGR factor score 3 for analysis 1
Chi-Square	100.796	94.591	113.253
df	2	2	2
Asymp. Sig.	.000	.000	.000

a. Kruskal-Wallis test
b. Grouping variable: Cluster number of case

Table 3: Differences in farm structure between farm groups

Farm group Characteristics	Group 1: Traditional and environmentally oriented farm group	Group 2: Economically oriented farm group	Group 3: Growth oriented, 'economies of scale' farm group
Future goals within group based on questionnaire definitions	Mental satisfaction of being a farmer, taking care of the environment	Good profitability, good liquidity and sufficiency in income financing, reasonable subsistence	Continuing growth, rationalisation of production, developing professional skills, continuity of family farm
Number of farms in group	59	134	67
Proportional production lines in groups:			
1. Cereal and other crop farms	37%	30%	46%
2. Horticulture (indoor and outdoor combined)	5%	4%	9%
3. Dairy farms	34%	40%	26%
4. Other animal production farms (cattle, pig and poultry)	12%	9%	7%
5. Mixed production	12%	17%	12%
* No statistically significant differences between groups			
Farmer's year of birth			
* No statistically significant differences between groups	Average: 1957	Average: 1960	Average: 1958
Working hours/year (average in 2004–2008) *x^2=7.148–8.932 *df=2 *p=0.011–0.028	in 2004: 2,597 hours in 2008: 2,317 hours Average 2004–2008: 2,482.4 hours	in 2004: 3,072 hours in 2008: 2,984 hours Average 2004–2008: 3,005.6 hours	in 2004: 2,527 hours in 2008: 2,280 hours Average 2004–2008: 2,395.4 hours
Arable land *x^2=17.348–19.745 *df=2 *p=0.000–0.000	in 2004: 40.5 ha in 2008: 42.0 ha Average 2004–2008: 41.32 ha	in 2004: 61.5 ha in 2008: 67.7 ha Average 2004–2008: 65.06 ha	in 2004: 57.4 ha in 2008: 66.7 ha Average 2004–2008: 62.48 ha

farms. After the clusters were defined, the formed farm clusters were studied in two ways. First, the foresight approach of farms was empirically tested according to each farm group. This was performed on the basis of the questionnaire carried out with the FADN farms and through the defined foresight approaches which were then reflected against the farm groups constructed. Second, the differences between farm groups according to the economic and structural indicators, which are presented in Tables 3 and 4, were analysed to see how the farm groups developed during the study period 2004–2008. The statistical significance between differences in the formed groups was studied by the Kruskall-Wallis test as it is suitable for ordinal variables. In the Kruskall-Wallis test performed, *p*-value was 0.000 (Table 2).

According to the results (Table 3), it seems that the three farm groups constructed differ from each other in terms of their future orientation and in terms of their economic and structural situation. The farms were divided quite equally in different production lines. However, there are relatively more dairy farms in the economically oriented farm group (Group 2). The farm size has increased most in Groups 3 and 2 as Group 1 has remained almost at the same level between the years 2004 and 2008. In general, the farm size was 31.52 hectares in the year 2004 and 34.18 hectares in the year 2008 (Niemi and Ahlstedt, 2009). Therefore, especially Groups 2 and 3 represent significantly larger farms than in general in Finland.

In Groups 2 and 3 (Table 4), debt-equity ratio, farm size development and turnover increase indicate that these are farms which have already invested strongly in the future. Also, mixed-production (mainly combination of livestock farms) is the most common in the economically oriented group. Cereal and other crop farms including horticulture settle themselves in the growth oriented farm group (Group 3). In the traditional and environmentally oriented farm group, the equity ratio was the highest, but also the average age of farmers was slightly the highest of all groups. The profitability coefficient remained modest in each farm group being the highest in Group 2. In general, the profitability varied between 0.52 to 0.64 and the farm family income from 25 000 Euros to 27 700 Euros in the years 2004 and 2008 (Niemi and Ahlstedt, 2009).

Table 5 presents the descriptive results of future orientation, structural development and economic situation of the farm groups. As the farm groups emphasised different future goals, there are also differences in the measured indicators.

4. Discussion

In this study, the used data was from the years 2004–2008. For more in-depth conclusions of economic development and structural changes, a longer time period would have benefitted our examination. The used methods of analysis were suitable for this study. Factor analysis of the future goals of farms was the

Table 4: Differences in economic indicators between farm groups

Farm group Indicator	Group 1: Traditional and environmentally oriented farm group	Group 2: Economically oriented farm group	Group 3: Growth oriented, 'economies of scale' farm group
Future goals within group based on questionnaire definitions	Mental satisfaction of being a farmer, taking care of the environment	Good profitability, good liquidity and sufficiency in income financing, reasonable subsistence	Continuing growth, rationalisation of production, developing professional skills, continuity of family farm
Turnover *x^2=16.067–21.842 *df=2 *p=0.000–0.000	in 2004: €91,630 in 2008: €105,027 Average 2004–2008: €96,449	in 2004: €145,581 in 2008: €200,078 Average 2004–2008: €167,265	in 2004: €116,750 in 2008: €152,241 Average 2004–2008: €132,399
Family farm income *Statistical significance only in 2004 and 2006 *x^2=17.348–19.745 *df=2 *p=0.013(2004), 0.012 (2006)	Minimum €20,393 Maximum €29,608 Average 2004–2008: €23,962	Minimum €30,125 Maximum €42,680 Average 2004–2008: €34,408	Minimum €21,390 Maximum €37,237 Average 2004–2008: €26,497
Profitability coefficient *No statistically significant differences between groups *x^2=0.772–4.192 *df=2 *p=0.123–0.812	Minimum 0.3 Maximum 0.63 Average 2004–2008: 0.46	Minimum 0.49 Maximum 0.73 Average 2004–2008: 0.56	Minimum 0.29 Maximum 0.72 Average 2004–2008: 0.51
Equity ratio *x^2=8.072–16.643 *df=2 *p=0.000–0.018	Minimum 85.3 Maximum 90.5 Average 2004–2008: 88.14	Minimum 74.6 Maximum 76.7 Average 2004–2008: 75.38	Minimum 75.1 Maximum 78.0 Average 2004–2008: 77.6
Debt-equity ratio* *x^2=8.006–16.331 *df=2 *p=0.000–0.018	Minimum 26.2 Max:40.84 Average 2004–2008: 34.03	Minimum 62.31 Maximum 71.07 Average 2004–2008: 67.45	Minimum 65.73 Maximum 83.13 Average 2004–2008: 74.27

*The statistical significance of the differences between the formed groups was measured by the Kruskall-Wallis test. In Tables 3 and 4, the minimum and maximum of x^2- and p-values are presented for 2004–2008.

starting point. It pinpointed the varying goals of farms and gave an opportunity to sum up the goals from the questionnaire as three future goal factors. After that, clustering by factor scores resulted in three farm groups which gave the possibility to evaluate the economic development and structural changes of farm groups. In the cluster analysis, also other solutions were tried but, in the end, the three-group solution was considered the best in this case. The reliability of the analysis was tested by examining the statistical significance between the differences in farm groups.

Our findings indicate that the three farm groups constructed differ from each other in terms of future orientation and in terms of structural and economic development. Table 6 presents the strengths and weaknesses of each farm group. Farms which are more traditionally oriented and emphasise environmental goals are very self-sufficient and their indebtedness ratio is relatively low. The weaknesses are their poor profitability and their passiveness in information retrieval. Their efforts on anticipating the future are also minor. The reason for this is that the farmers of these farms are most often retiring ones. Surprisingly many of them do not have any plans for transferring the farm to a descendant. These are mainly farmers which will lease or even sell the farm and the arable land to active farmers when retiring. There was 33% of the arable land under lease in Finland in the year 2011. Leasing has increased considerably during the European Union membership as a result of the structural change in farm structure (Niemi and Ahlstedt, 2009). An increase in farm size has been gained mostly through leasing. Also as a result of uncertain profitability, there are difficulties in finding competent and motivated continuators for smaller farms. Also part of this group may become part-time farmers.

Those farms focusing on economic success emphasise more all of the three time-perspective, i.e. operational, strategic and visionary, approaches on planning. Also, their foresight approach is preactive by nature. Furthermore, they have steady growth and relatively steady profitability. The weaknesses are still their poor profitability and only satisfactory indebtedness ratio. The growth oriented farms suffer from negative changes in market prices and their profitability varies most of the groups. The strength is their willingness to invest in agricultural production and increasing the farm size and, therefore, their ability to anticipate and adapt to the future requirements concerning farm structure and size.

Farm management today is extended from production management to managing the operational environment as a whole. Therefore, there is a need to include a longer time perspective in the planning practices of farms. This means that the approaches of strategic management as well as the anticipation of alternative future paths should be adopted to farm management. In addition to the operational management procedures, there should also be a shared vision and strategic goals for a farm enterprise and its workers in the long run. This is due to the increasing farm sizes and the size of business overall. A shared strategy means that anyone

Table 5: Descriptive result matrix of farm groups

	Group 1: Traditional and environmentally oriented farms	Group 2: Economic success oriented farms	Group 3: Growth and development oriented farms
Future goals within group (based on questionnaire definitions)	Mental satisfaction of being a farmer, taking care of the environment	Good profitability, good liquidity and sufficiency in income financing, reasonable subsistence	Continuing growth, rationalisation of production, developing professional skills, continuity of family farm
Planning perspective and foresight approach	Operational and strategic planning practice, reactive approach to changes, passive in information retrieval	Operational, strategic and visionary planning practise, from reactive to preactive approach to changes, most active in information retrieval	Strategic and operational planning practise, from reactive to preactive approach to changes, rather active in information retrieval
Structure of farm enterprise (years 2004–2008)	Clearly smallest farms as for economic size (turnover), farm size (area under cultivation), no growth in cultivated area or turnover	Clearly highest number of working hours, biggest in economic and farm size (turnover and area under cultivation), steady growth in cultivated area, quite rapid growth in turnover	Least working hours, by turnover bigger than Group 1, by farm size almost as big as Group 2, rather big in economic size, steady growth in cultivated area and in turnover
Phase of life cycle on farm (years 2004–2008)	Most farms cannot define the point in time for transferring the farm to a descendant, precious little recently or in near-future transfers, the statement ''farming is coming to an end'' describes well the better part of farms	Significantly many of transfers are planned to happen in 5–15 years' and more than 15 years' time, just 9% of farms in group recently conducted the transfer of the farm to a descendant	Significantly many of transfers are planned to happen between 5 to 15 years
Economic situation of farm (years 2004–2008)	By far poorest profitability, but most self-sufficient and lowest indebtedness ratio	Highest farm family income, good self-sufficiency, satisfactory indebtedness ratio	Best in return on total assets, biggest changes in profitability between years, good self-sufficiency, good/satisfactory indebtedness ratio

who will be involved in the same value creation process must end up at the same goals and objectives, the shared destination. And to do so, all involved require the same road map. Our findings indicate that if the planning is well-balanced between operational, strategic and visionary time frame and the foresight approach is preactive or proactive by nature, the farm categorises as growth-oriented and gains better profitability. But, there is also a downside to this. At this phase, farms usually have invested money to gain this growth and, therefore, are in debt. Heavy investments also mean an increased risk of business failure. From the planning point of view, there is a need to develop such strategic management tools for value creation which meet the demand of small-size enterprises which farms still usually are. According to Shadbolt (2008), using strategic tools would provide farm managers an on-going learning opportunity as it facilitates in-depth discussion about the vision, strategy and critical success factors of the farm business and translates them into specific measures and objectives in action.

5. Conclusions

The goal of this paper was to analyse what kind of future goals and foresight approaches farms have. Also, the link between the stated future goals and the success of the farms as measured by economic and structural indicators (e.g. profitability, growth) was studied through available FADN data. Surprisingly, there has been little research examining the relationship between

Table 6: Strengths and weaknesses of three farm groups

	Strengths	Weaknesses
Traditional and environmentally oriented farms	Very self-sufficient, relatively low indebtedness ratio, possibilities to capitalise achieved wealth	Poor profitability, passive in information retrieval, foresight activities minor, poor productivity
Economic success oriented farms	Planning focuses on operational, strategic and visionary time frame, steady growth, good self-sufficiency, active in information retrieval, pre-active approach in business helps in uncertain market environment, relatively steady and also best profitability of farm groups	Satisfactory indebtedness ratio, poor profitability
Growth and development oriented farms	Willingness to invest in increasing farm size, benefits most of changes in market environment, good self-sufficiency	Suffers most from negative changes in market prices, considerable indebtedness ratio

the future orientation of the farm (i.e. stated future goals, a foresight approach) and farm performance in farm management. Using survey data, we settled on three different farm groups through factor and cluster analysis. They represented differences in future orientation and in foresight approaches asked. According to this study farms have different emphasis on future orientation. Some of them lean on traditional values as being a farmer, some of them are eager to grow their business and are more entrepreneur oriented. Our findings indicate that the stated future goals are also visible in farm performance. As the future goals and the foresight approach were a farmer's subjective statement, it also tells the farmer's motivation to improve and develop farm management behind the goals. Before using specified strategic tools, it is crucial to build managerial competence. Especially in farm management, in which the business is based on the laws of nature, the competence of biological processes in relation to business logics (revenues versus cost) is important.

Overall, our study proposes new insights into varying future strategies of farms and also possible benefits of long-range planning in farm businesses. It also brings into the discussion the need for applicable strategic and foresight tools for farm enterprises. Such tools are available e.g. The Balanced Scorecard (Kaplan and Norton 1992), but these have to be designed to fit farms' purposes. These kinds of tools also contribute to a disconnection between monitoring and strategy, as they force entrepreneurs to measure their activities in a balanced manner (Shadbolt 2008). Furthermore, if such tools are applied, their results benefit farm enterprises in achieving a better and comprehensive management level with operational, strategic and visionary perspectives. One example of a strategic tool is to compare the situation of a farm with other farms alike. For these purposes, it is crucial to develop and utilise farm performance databases. For example, the European level FADN system and its database give farms opportunities to diversely benchmark their structural and economic performance between farms and production lines.

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REFEREED ARTICLE

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Training farmers in agri-environmental management: the case of Environmental Stewardship in lowland England

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ABSTRACT

Research on voluntary agri-environmental schemes (AES) typically reveals limited engagement on the part of most participants, with the majority enticed into participation by a combination of attractive payment rates and compatibility with the existing farming system. Commentators have argued that changing farmer attitudes towards environmental management should be an outcome of AES. One possible way of doing this is through the provision of educational and advisory programmes designed to help farmers understand why certain actions are required and how to undertake appropriate conservation management. Based on interviews with a sample of 24 farmers in the East and South West of England this paper explores farmer understanding and concerns regarding the management requirements of two options implemented under the Entry Level Stewardship (ELS) scheme. It considers the short and medium term impacts of participating in bespoke group training events and discusses the potential of training to improve the effective implementation of agri-environmental management at the farm level. Analysis of the impact of training reveals that participation in bespoke group training events can fill knowledge gaps, equip farmers with a range of management skills, improve confidence and engender a more professionalised approach to agri-environmental management.

KEYWORDS: Agri-environmental schemes; Entry Level Stewardship; farmer knowledge; training

1. Introduction

Since the late 1980s voluntary agri-environmental schemes (AES) have provided financial incentives for farmers to adopt management practices designed to maintain or enhance the environmental value of their land. Although participation is voluntary AES are characterised by sets of codified management prescriptions that farmers must implement. If it is assumed that these management prescriptions are appropriate for the stated objectives, the actions of the farmer become critical to the success of AES. Primdahl *et al* (2010) argue that AES management practices are often based on general beliefs about the link between specific management practices and environmental outcomes rather than on scientific evidence, although in the case of the British AES, many management prescriptions derive from rigorous ecological studies (e.g. arable reversion (Pywell *et al.*, 2002); bumblebee habitat (Pywell *et al.*, 2005); winter bird resources (Henderson *et al.*, 2004)). Recognising the important role of the farmer, early social science studies considered the success or failure of AES in terms of farmer uptake and focused largely on numbers of farmers enrolling, area enrolled, speed of uptake, and barriers to entry (e.g. Whitby *et al.*, 1994). It was often assumed that sufficient levels of uptake and removal of barriers to entry could be taken as a proxy indicator of scheme success. Early social science research on AES was often influenced by the innovation adoption model. For instance, Morris and Potter's (1995) study drew on innovation adoption theory to explore the uptake of both actual and hypothetical schemes. Despite quite high levels of uptake the research revealed high rates of 'passive adoption' whereby participants were motivated by financial gain and failed to engage with the environmental objectives of the schemes. While so-called 'traditional indicators' (Wilson and Hart, 2001) such as uptake can provide some measure of a scheme's success, research suggests that it is the level of understanding and engagement with scheme aims and objectives that often matters (e.g. Morris and Potter, 1995; Wilson, 1996; Lobley and Potter, 1998; Kaljonen, 2006). Indeed, it has become clear that AES participation cannot be viewed as a simple dichotomous decision to participate or not participate. Once the decision has been made to join a scheme, farmer engagement with the principles and objectives of the schemes varies but research has typically revealed limited engagement with the environmental principles of the schemes on the part of most participants, with the majority enticed into participation by a combination of payment rates and compatibility with the existing farming system (Lobley and Potter, 1998; Wilson and Hart, 2001).

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It has been argued therefore that a shift to a more pro-conservation attitude should be both an outcome of AES and an important indicator of scheme success (e.g. Lowe *et al*., 1999; Wilson and Hart, 2001). Riley (2011) argues that a significant gap in AES research is studies that adopt a longitudinal approach which revisit the same scheme participants and explore changes in attitudes over time. In the absence of such research the evidence that does exist suggests that AES have had limited success in promoting enduring changes in participants' attitudes and behaviour (e.g. Burton and Paragahawewa, 2011; Burton *et al*., 2008). One suggestion advanced for encouraging such a change is the provision of educational and advisory programmes designed to influence attitudes and, most importantly, help farmers understand why certain actions are required, and how to undertake appropriate conservation management (Falconer, 2000; Wilson and Hart, 2001; Juntti and Potter, 2002).

In contrast to the large number of studies exploring the motivation for the farm level adoption of AES, the aim of this paper is to consider the extent to which farmers are confident in their ability to implement AES management prescriptions and how training and advice might influence farmers' understanding and implementation of AES management prescriptions. Adopting a qualitative case study approach, the paper explores farmer understanding and concerns regarding the management requirements of two specific options implemented under the Entry Level Stewardship (ELS) scheme in England. It then goes on to consider the short and medium term impacts of participating in bespoke group training events and discusses the potential of training to improve the effective implementation of agri-environmental management at the farm level. Our concern is with the potential of training to influence the performance of agri-environmental management rather than the environmental outcomes of agri-environmental management.

2. Development and implementation of AES

The development of voluntary AES in the UK is typically traced back to the late 1980s, following the 1986 Agriculture Act and the introduction of Environmentally Sensitive Areas (ESA) in 1987 (see Potter, 1998 for an analysis of the evolution of agri-environmental policy in the EU and USA). The original ESA programme was complemented by the Countryside Stewardship Scheme (CSS) in 1991 which, unlike the ESA approach, was focused on the so-called wider countryside outside of specially designated areas. Various other smaller scale and shorter lived agri-environmental schemes have been implemented but during the 1990s, in England, ESAs and CSS were the main AES (with similar schemes in the other parts of the UK).

Following the 2003 CAP reforms and a review of AES the ESA programme and CSS were closed to new entrants and a new scheme, Environmental Stewardship (ES) was launched in March 2005 (Defra and Natural England 2008). ES consists of four elements: Entry Level Stewardship (ELS), Organic Entry Level Stewardship (OELS), Uplands Entry Level Stewardship (Uplands ELS) and Higher Level Stewardship (HLS). Overall ES has similar objectives to the previous schemes and in addition aims to have a much wider impact by bringing the majority of farms under at least the most basic level of agri-environmental management represented by ELS. By February 2013 there were over 42,000 ELS agreements covering close to six million hectares (or 62% of England's Utilized Agricultural Area). If the now closed, 'legacy' schemes are included 70% of England's UAA is under some form of agri-environmental agreement, with an annual budget of £414m[4] (NE 2013). In terms of design, ELS employs similar prescriptions to those developed under the previous schemes, but with a simpler and more inclusive framework. ELS is voluntary and non-competitive and is available to all farmers. Farmers can choose their management options from a list of over 60 that are available. Each option is associated with a specific number of points per hectare or linear metre. In order to qualify for a flat rate payment, participants must select management options to reach the target of 30 points per hectare (where 30 points=£30) for each hectare of the farm. ELS options range from those providing a basic level of management such as less frequent hedgerow cutting and extensive grassland management, through to the creation of new habitats such as flower-rich field margins.

Although generally hailed as a success due to the considerable uptake achieved, it has been argued that the wide range of management options available gives participants the opportunity to select options requiring little or no management change and that consequently ELS may buy little additional environmental benefit (Hodge and Reader, 2010). In addition, a significant body of research suggests that although farmers may be willing to implement AES management prescriptions, such participation tends not to be associated with enduring attitudinal and behavioural change (de Snoo 2013; Burton *et al*., 2008). Studies suggest that there is a spectrum of participation in AES reflecting different levels of engagement with scheme aims and objectives (Lobley and Potter, 1998; Wilson, 1996; Morris and Potter, 1995). Typically, research has revealed limited engagement on the part of most participants (Wilson and Hart, 2001) with the majority enticed into participation by a combination of payment rates and compatibility with the existing farming system (Schenk *et al*., 2007; Defrancesco *et al*., 2008; Lobley and Potter, 1998). While such participants may abide by the letter of the agreement, they can fail to understand the reasoning behind management prescriptions. This can lead to attempts to 'cut corners', unintentional breaches of agreements and the accusation that AES payments can be 'temporary bribes' (Morris and Potter, 1995).

Burton *et al*. (2008) argue that one of the reasons why AES have not engendered a shift towards a more conservation orientated farming culture is that, in contrast to production-orientated farming where farmers can display their cultural competencies through the visible impact of their management on their fields, yields, and so on, AES effectively de-skills farming practice: '… once the scheme is established, the farmer's ability to display skill through conservation work is

[4] In early September 2013, £1 was approximately equivalent to $US 1.56 and €1.18 (www.xe.com).

limited' (p.26). Consequently, by removing the need for skilled, production orientated agricultural land management Burton *et al*. argue that AES 'fail to allow farmers to perform identity enhancing behaviour' (p.27). AES prescriptions are often just that; a series of management prescriptions given in a fixed format that limits farmers ability and imagination to deal with the situation and which effectively deskills (to borrow from Burton *et al*. 2008) and disaffects them. That said Burton and colleagues appear not to consider AES options that require on-going and active management. Amongst the various AES options some involve predominantly passive behaviour on the part of land managers (such as low fertility grassland options) and offer participants little opportunity to demonstrate visible conservation skills or those associated with production-orientated agriculture. Others however, require more active and on-going management (e.g. pollen and nectar plants for bees and butterflies or wild bird food resource options) and arguably offer farmers the opportunity to demonstrate agri-environmental management skills and prowess in a way that is visible to others.

It has also been suggested that providing more information to farmers and the provision of training can encourage the development of more pro-conservation attitudes. Wilson and Hart (2001) argued that training would lead farmers to a greater feeling of pride in their environmental management. They argued that educational programmes could help shift farmers from an essentially utilitarian stance towards more conservation-oriented attitudes and that this should be seen as an important indicator of scheme success. It has also been argued that training may be crucial in helping farmers understand *why* certain actions are required as well as *how* to undertake conservation management (Falconer, 2000). Nevertheless, there have been few, if any, attempts to explore how such a shift can be effected through the provision of training, although some research suggests that AES are more likely to succeed where farmers receive expert advice and/or training (e.g. Kleijn *et al*., 2001).

3. Farmer knowledge

Calls for the expansion of provision of environmental training and advice do not imply that farmers are lacking in knowledge. Farming is increasingly a knowledge-rich activity. In addition to farmers' detailed 'local' knowledge of environmental interactions and processes generated through learning from experience, an increasing proportion hold degrees or other HE qualifications in agriculture and closely related subjects – nearly 20% in the UK in 2010 according to the Quarterly Labour Force Survey (Wallace and Jack 2011). Although this is low compared to other sectors it represents a doubling in just over a decade (see Gasson 1998) and because the operators of larger farms tend to be better qualified, the proportion of land farmed by educationally well qualified farmers or managers far exceeds the 20% figure (Brassley 2005). Although many farmers are able to distinguish a species rich wildlife meadow from one that is less so by observing the number of different wildflowers that grow there and the butterflies that fly around, they may be less able to describe the associations of the butterflies' lifecycle and the ecological attributes of particular plant species or plant communities. They may have observed that a greater number of pesticide applications has resulted in less wildlife on their land but they are not necessarily in a position to explain causal processes. Tsouvalis *et al*. (2000), using the example of precision farming, note that 'although many farmers know their fields intimately, the complexity of biophysical processes is such that […] the *'why'* - often remains. This is where science has made its inroads, prompting itself many of the questions it now tries to answer' (p. 917). In the case of AES, farmers are called on to apply management prescriptions that have been devised by environmental experts who hold the knowledge of the invisible '*why*', but the medium they have designed to communicate through offers only the '*how*' (i.e. management prescriptions). AES management practices derived from the disciplines of ecology, biology, landscape ecology and history, and agricultural science form part of a 'a heavily 'scientised', codified, bureaucratized and centralized approach to knowing nature on farms' (Morris, 2006, p. 116) that may prevent or limit farmers' complete comprehension about the purpose of the suggested tasks.

Knowledge alone however, is not enough to achieve agri-environmental objectives. Research in other areas of environmental policy strongly suggests that awareness raising, education and information are not sufficient to bring about a change in behaviour, which may be subject to a range of other barriers such as a lack of incentive and lack of experience of the positive impacts of a behavioural change (e.g. Barr and Gilg, 2007; Kollmuss and Agyeman, 2002; Maiteny, 2002; Owens, 2000). It has been suggested that for farmers to change the way they farm to benefit farmland birds, they need to go through a process that: increases awareness of the problem of declining birds; promotes understanding that farming methods have caused declines; provides financial incentives to change farming methods; and gives information on approaches to help birds (Smallshire *et al*., 2004). It has also been argued that in order to bring about a change in behaviour, factors such as knowledge, awareness and incentives need to be combined with a strong 'locus of control' (an individual's perception of whether they can bring about the desired change through their own behaviour). A strong internal locus of control is associated with beliefs that environmental action can bring about desirable change (Kollmuss and Agyeman, 2002). In other words, in addition to incentives, information and support, individuals need to *believe* that their actions and behaviour can make a difference.

In the case of agriculture it would be naive to argue that training and education alone will necessarily lead to improved environmental outcomes. However, there are already strong policy signals encouraging the uptake of AES in the form of economic incentives and growing recognition that the supply of rural environmental goods is an important part of the social contract between farmers and taxpayers. Education and training may provide an opportunity to reinforce existing policy signals and help farmers to understand why certain management practices are required. Moreover, demonstrating to farmers the positive environmental outcomes of their agri-environmental management may help foster a stronger internal locus of control and create a positive feedback effect. It is against this background that the remainder of this paper considers farmers' confidence in their ability to understand and implement AES management prescriptions (i.e. it identifies if there is a knowledge/skills gap in relation to agri-environmental management) and their response to training in agri-environmental management.

4. Methodology

In order to explore the impact of training for agri-environmental management, two broad groups of farms were selected for study: arable/cereal farms located in the intensively managed landscape of eastern-central lowland England and arable and mixed farms in South West England[5]. In each area, 12 farmers were recruited to take part in the research over a five year period. All farmers recruited in this research were participants in ELS.

In order to explore the impact of training on agri-environmental management it was necessary to identify land management options that require specific and specialised knowledge. For instance, some of the 'passive' low intensity management options such as low input management of permanent grassland (a very popular ELS option) are likely to be easier to undertake in the absence of specialist advice and training than active habitat creation and enhancement options, which arguably require a greater degree of skill and on-going management. In addition, the number of ELS options selected for investigation needed to be limited in order to maximise the potential effectiveness of training and facilitate analysis of the results. Therefore, the study focused on two specific options for arable field margins: the Wild Bird Mixture (WBM) and Pollen and Nectar Mixture (PNM). WBM was designed to provide food for birds by making available a seed-bearing crop in arable landscapes during the winter. PNM aims to boost the number of pollen and nectar feeding insects, including butterflies and bumblebees, by sowing and maintaining a range of selected flowering plants. These options have been proven to provide excellent resources for their target species (Pywell *et al*. 2012; see this as well for a full description of WBM and PNM). They also require moderately skilled management for both the establishment and on-going persistence of the option, including site preparation, choice of seed mixture and weed management. Twelve of the participating farmers had WBM as part of their ELS agreement, 12 had PNM and of these 9 had both options.

24 on-farm face-to-face baseline interviews were conducted in 2007. The interviews typically lasted 60–90 minutes and were recorded for later transcribing. The interviews were designed to explore farmer attitudes to AES in general, their history of environmental management and their attitude towards ELS in particular. In addition, the interviews explored farmer understanding of the management requirements for WBM and/or PNM and identified any concerns that they had regarding their ability to comply with the requirements of these options. The mean age of the interviewees was 48. Fifty-seven per cent had a technical qualification in agriculture and 26% had obtained a degree in agriculture or closely related subject.

Following the baseline interviews, group training events were convened in each study area.[6] The training was provided by a highly knowledgeable, professional trainer who has long experience of providing agronomic and, latterly, AES advice to individual farmers, and of testing and experimenting with agri-environmental options. The training was tailored towards the management requirements of WBM and PNM. The design of the training course was informed by the trainer's previous experience in advising farmers and his discussions with the project team about the aims and scope of the research[7]. Each participating farmer received £50 towards their expenses for attending the training.

The training day was composed of two parts; the 'theoretical' and the 'practical'. The theoretical part included a general introduction to the background and rationale of agri-environmental schemes, as well as scientific information on habitat management requirements (including a brief introduction to ecological succession). During this part of the training findings from previous scientific experiments and real field situations were presented, as well as suggestions on appropriate management and use of combinations of species under different landscape conditions. As well as introducing the farmers to a number of useful concepts, the purpose of this part of the training was to demonstrate that: agri-environmental management options are based on rigorous research and so have a solid basis; environmental management could coexist with arable farming; farmers through their actions and attention to detail could influence the 'quality' of such environmental management; and a professionalised approach to environmental management could produce results. Accordingly, the trainer opened his session referring to habitat creation:

> *'…today, what we're actually being asked to do is grow a different crop. What [is] a crop? It's something that sticks out of the ground and requires management. Can be wheat, oilseed rape, dickybird food, really doesn't matter.'*

He went on to say that: '*… habitat to me is just another crop. It should be to all of us.*' His message was that farmers should adopt the same professional approach to habitat management as they do to other crops.

The practical part of the training was a farm walk, on a nearby farm, which included a number of stops to examine existing relevant applications of agri-environmental options. The participants had the opportunity to compare on-the-ground examples with the research-based findings presented to them earlier in the day, and to discuss and distinguish between more or less successful management treatments. After the farm

[5] The choice of these two broad locations was in part in order to explore how the local/regional landscape context may influence agri-environmental outcomes (work that is not reported on in this paper) and also to facilitate relatively easy access by different members of the research team, some of whom were based in the south west while others were in central lowland England.

[6] 23 of the 24 farmers attended the training. One farmer was accompanied by his agronomist.

[7] Following on from the training the trainer developed an idea for the production of a DVD with advice on the WBM and PNM options. The DVD was produced under the auspices of Defra and distributed to all farmers who joined or re-joined ES.

walk the participants engaged in a detailed discussion of issues that arose during the day including technical aspects of implementation such as seed mix, sowing depth and aftercare. Evidence suggests that the interaction between participants in training sessions provides the opportunity to compare attitudes, represents an additional source of information, and increases the probability of making a behavioural/farm management change (Kilpatrick, 2000).

A final set of face to face interviews was carried out in 2010 (although one farmer terminated the interview part way through). The interviews were again conducted on farm and explored participants' experience of managing their ELS options and their ability to recognise successful implementation, gathered detailed information on the implementation and management of options and explored the longer term impacts of training on knowledge, confidence and ability.

5. Farmers' confidence in their agri-environmental land management skills and ability

Many of the farmers participating in the research were familiar with conservation practices, although 11 had not previously been involved in formal voluntary agri-environmental schemes. This is a reflection of the rationale of ELS which is designed to appeal to large numbers of farmers who have not previously participated in schemes. This lack of formal participation experience may have implications in terms of knowledge, familiarity with certain tasks and the necessary confidence to manage habitat creation options such as WBM and PNM. On the other hand, only 4 farmers admitted to being apprehensive about participating in ELS. Most of those who appeared not to be apprehensive had no previous experience of participation in AES. It might be expected that farmers with no previous experience of AES would be more sceptical about their ability to comply with the management prescriptions. Their lack of apprehension may reflect confidence in their ability to manage the options, or perhaps their unawareness of the real objectives and requirements of the scheme. Of those who did admit to feeling apprehensive, this was most often connected to their concerns about the inspection regime and meeting the practical requirements of the scheme.

The baseline interviews included a discussion of the extent to which the interviewee was confident of their ability to meet the management requirements detailed in the ELS handbook at the time. Despite the overall high level of confidence reported above, discussing these more detailed management issues revealed a number of concerns regarding the ability of farmers to comply with specific management requirements. Many (15 farmers) expressed concerns with complying with management prescriptions regarding pesticide applications. As one farmer put it, although they had readily applied to join ELS, it was only when they started implementing their agreement that they realised they were unsure of what to do:

> *'Well when they brought all this Entry Level in… … it's alright handing out a handbook and saying 'put wild bird mixture in, put field corners in, do this, do that'. It was all brought in and we all signed up quickly because we knew the money was going to be there, but we never really had a clue until we started going to the sort of things you are doing'.*

A significant minority (7 farmers or 30%) thought that establishment and/or re-establishment would be difficult as the following example illustrates:

> *'…[L]ike I said… we grew kale, quinoa and triticale. Now, the quinoa and the triticale is finished. The only thing left standing is the kale. Now unless I do something about that in the spring… the only crop that'll be there will be kale. Now you can't plant… triticale or quinoa into a kale crop because the kale will just smother it. You've got to really rip the whole lot up, plough it and do it all again. Now, I'd have to get some advice about that… I'm not quite sure about it because I've never done it before, you see? Because like before we done this we've only ever grown kale on its own, you see?'*

PNM is probably a more demanding option in terms of management input. WBM management is similar to that for game cover crops (although involving a more complex species mix as alluded to above) and includes relatively routine tasks such as annual or biennial re-establishment by drilling seed. In contrast, PNM involves an unfamiliar 'crop' of wildflowers, specific establishment methods, and monitoring to assess when re-establishment is required (after 3 or 4 years). Again, a significant proportion of respondents felt that establishment and re-establishment of the 'crop' would prove difficult as is illustrated by the following quote:

> *'The re-establishment … I suspect that is going to be moderately difficult … not knowing quite when to do it. It goes back to the thing that I had nobody to tell me. And I guess unless we farmers that are doing it get together with some professionals … you know we are not really equipped to know quite how to do that'.*

These comments point to some specific skills/knowledge gaps and when asked, 21 of farmers participating in the research said that they thought that they could benefit from training related to the management tasks for WBM and PNM. It is interesting to note here that 11 out of 12 farmers who had previously participated in AES felt that they needed further advice and attended the training programme. The willingness of these farmers to receive further training and advice on ELS tasks may signify two things. First that they realise that managing their land under the prescriptions of the agreement is not as straightforward as it first appears to be, and second that farmers with more experience recognise the importance of knowledge and become more receptive. In turn, this would imply that engagement with knowledge is associated with attitudinal and behavioural changes.

Attending the group training was, for a number of farmers, an opportunity to see what other farmers were doing and to improve their confidence: '*… [W]ell … to see how others are managing their plots … hum … and really just … to give me a bit of confidence … to make sure I am doing it right.*' Others identified quite specific training and information requirements:

> *'Well, I am hoping that I can… learn whether there is any way we can improve our existing ELS agreement… I would certainly appreciate with the wild bird mix any advice. I know you can get it but there's so many wild bird mixes you can put in, but if*

someone would say to me, well these really are the bees knees, this is the sort of mix you should be looking at because I haven't had any real advice about that'
'I don't know enough about the different varieties of everything that has been put in there. I mean, you know, I wouldn't know a trefoil even if it bit me [laughs]!… I don't know whether I should be cutting it off or whether I should be leaving it to grow and perhaps it'll reseed itself…'

Another farmer revealed his frustration and confusion regarding the most appropriate management to apply:

'Hum … we took some silage off it but we didn't know whether to top it or not …or leave it as it is. I think we will leave it as it is. … I mean … we have got the topper on … I don't know whether to top it all, or top half of it or top it a bit more or … I don't know what to do really.'

The comments made are in contrast to the argument by Burton *et al*. (2008) that AES removes much of the skill required for managing land. Clearly a number of the farmers recognised that on-going management requires both skill and knowledge. As one farmer put it '*I am a trained cereal grower. I need new input as an environmental land manager*'. More importantly, these comments demonstrate the point that the instructive nature of AES prescriptions, focussing on the *what* rather than the *why,* limits the potential for effective implementation of the scheme. This can be either because not enough information is provided to help farmers successfully perform the tasks, or because the restrictive nature of the prescriptions prevents farmers from experimenting with different approaches.

6. The impact of training for agri-environmental management

The impact of training can be identified in the short term impact on farmers' intentions and the longer term impact on their attitudes and actions towards agri-environmental management. In the short term the training was clearly a success and had a notable impact on the participating farmers. Immediately after the group training events, participants completed an evaluation questionnaire designed to capture information regarding how useful the day was and the likely impact on how participants manage their ELS options. Response to the group training events was very positive with one farmer simply stating '*I wish I could have done that course before*'. The majority (14) reported that the day was 'very enjoyable', and most (16) agreed that the information presented was 'very useful'. One farmer reported that the training: '*Made me look at the ELS from a more informed and hopefully different angle*', while another indicated that the training had provided him with knowledge that he could usefully apply to the management of his ELS land: '*I now have some idea of how to manage the margins that I have sown as no one is going to show me*'. Others felt that the training had provided them with new techniques and ideas for mowing, seed mixtures and overall management. In addition, 21 of the farmers felt that the training would influence the way which they manage their ELS land, with some evidence that they would adopt a more professionalised approach to agri-environmental management, for example, '*I will now try and make more time to treat ELS options as I do the rest of the farm.*'

The comments made by the farmers also indicate that the training began to address some of the issues regarding knowledge, experience and confidence that emerged from the baseline interviews. For instance a number indicated that the training would have an impact on their locus of control, reporting that they had more confidence in their abilities and a sense that their actions could make a difference in terms of biodiversity. For example,

'It made me trust that I can do a better job for wildlife'
'I feel more confident that the effort I put in will be rewarded with results.'

These comments indicate that in the short term the training had an impact on farmer attitudes, suggesting that the participants would be willing to put more effort in to agri-environmental management and that they had a greater sense that their effort could yield improved results. In addition it also addressed some knowledge gaps on technical aspects of management.

Despite these positive responses offered in the enthusiastic aftermath of a successful training event, it is only over the longer term that it is possible to identify the more enduring impacts of training. During the final round of interviews in 2010 the majority (18) reported that the training had a significant or very significant impact on the management of their of ELS options. This indicates that the short term training effect identified above had sticking power. The training impact can be seen both in technical aspects of management (such as seed mix and handling different types of seed at the same time), in farmers' attitudes and in a sense that they can do a better job on environmental management. Few reported that they had not implemented any of the training provided. Reasons for this varied from feeling that they were already doing a good job and did not need to make any changes to one farmer who admitted that although he was initially keen, ultimately he just did not bother to make much effort to manage his ELS options.

For those farmers who did implement the training, changes to the seed mix used was by far the most frequently applied aspect of the training followed by other technical elements such as the mowing regime. In addition to impacts on technical aspects of agri-environmental land management in some instances the training encouraged farmers to modify their essentially utilitarian attitude towards participation. For instance:

'…. the thing that really struck me the most was that … I was looking in from a farmer's point of view and not in terms of what I was trying to achieve. I was just trying to get the money and do it as cheaply as I could. And, then I realised, well they are giving me the money for a reason. I should actually be managing it to create habitats for birds. Not just for the money. So, I think that is the biggest thing that came out [of the training].'

Another reported a very similar impact resulting from participating in the training:

'I think you are more inclined then to do it. Hopefully you will try and do it well. Whereas before it was 'they have made me do it to get this money'. But you know, why bother really?… and I think,

you know, it all brought it home that actually it is possible to do some good, yes, and it is not just the figment of some bureaucrats imagination, you know?'

The training was also able to help address some of the issues raised in the first round of interviews concerning a lack of confidence due to being unsure of quite what was being asked of ELS participants and why:

'… seeing it we were given encouragement. That was the greatest thing because otherwise you are just left on your own to get on with it and you don't really actually, not many farmers I think know what they are doing or what they are trying to do … and just explaining all the whys and the wherefores. Why you are putting in two different seeds, you know, for the two different winters and all that sort of stuff and again we picked up tips about establishment.'

Another farmer commented that '*Well it is not how, it is the why. That is the important thing that we got out of it.*' Another recognised that although the skills and techniques required were essentially those of farming:

'…. obviously that is something, almost like a new crop that you haven't ploughed before. … Although there was nothing in there that was sort of like new. What you are trying to achieve and do was new. So obviously it was a different approach.'

It would seem therefore that carefully designed training has the potential to influence the performance of agri-environmental management and the attitudes of farmers.

7. Conclusions

The body of research on farmer engagement with AES points to the apparent failure of the approach to bring about meaningful and enduring changes in farmer attitudes and behaviour regarding environmental management (eg Burton *et al* 2008) which in turn frequently leads to calls for training and awareness raising (e.g. Wilson and Hart, 2001). AES management prescriptions are derived from 'scientised' and codified environmental knowledge. In communications with farmers, the knowledge flow of AES is dominated by '*how*' issues which results (particularly in the case of ELS) in an instructive approach, treating farmers as agri-environmental technicians, with an emphasis on 'what to do' with much less concern given to explaining the '*why*' of environmental management requirements. If farmers are to fulfil the role of knowledgeable and professional environmental managers, questions of how, what and why all need to be addressed (Ingram 2008).

Despite the original intention that ELS could operate as a 'broad and shallow', 'hands off' scheme with little or no specialist advisory and/or training input required, interviews with farmers in two different areas of England revealed concerns regarding technical aspects of both the establishment and on-going management of particular options. To some extent this is because ELS has achieved what it set out to do. It has brought a group of farmers without previous agri-environmental management experience into a broad-based entry scheme. Such farmers have sometimes underestimated the management requirements of the scheme and they often lack the experience and confidence to manage their ELS options for maximum environmental benefit. The instructive, prescriptive nature of ELS may restrict farmers' freedom to implement imaginative solutions but unfamiliar seed mixtures (and seed sizes) establishment and maintenance practices have also created a need for training and highlighted specific areas for improving knowledge exchange between farmers and AES experts.

It is perhaps not surprising then that the farmers taking part in this research were mostly very receptive to the idea of agri-environmental training. The training provided impacted both upon farmer's technical competencies and also upon their attitudes towards AES. The group training events were popular with farmers and created a positive attitude towards ELS management. The farmers also benefited from being with peers in a similar position to themselves and by being able to share their experiences of managing ELS options. The training addressed a number of concerns farmers had expressed in earlier interviews, boosting confidence and providing practical knowledge of techniques, seed mixtures, etc. A number of the comments made about the training suggest that it impacted on farmers' locus of control, in that it gave them the skills, knowledge and confidence that their management actions could produce an improved environmental benefit. To this extent the training began to supply answers to the missing '*why*' questions and by demystifying some of the environmental science began to provide participants with the 'feel for the game' identified by Bourdieu (1985) as so important for linking conceptual knowledge with one's practical everyday activities. This involves the application of newly acquired knowledge but often it is perhaps more prominent when existing knowledge has to be applied in different ways such as in sowing a mixture of unfamiliar seeds at unfamiliar depths. Moreover it involves a shift in the way of thinking about agri-environmental management and a willingness to treat 'environmental land' in the same way as the rest of the farm. In contrast to deskilling this provides confidence for a more professionalised approach to agri-environmental land management, itself an aspect of a wider professionalisation of agriculture (Brassley 2005).

It would be costly to roll out a programme of small group training to all AES participants and as we have argued above the type of training developed for this research is more relevant to options requiring active and specialised management. Training targeted towards farmers with the type of options requiring specialist knowledge and active on-going management, could be delivered relatively cheaply in the context of the overall AES budget. One approach would be to make receipt of AES funds conditional on taking part in a short training course. Although this has some appeal it could alienate some farmers and if it was only associated with 'active management' options it could lead to reduced take up of such options. An alternative would be to develop an optional training course designed to appeal to those with certain options in their AES agreement. It would also be possible to design a course and subsequent refresher courses so that they accrued ELS points and contributed to the required 30 points per ha. Further research would be necessary in order to identify the most appropriate and effective content for such a course. Consideration would also have to be given to the identity of the trainers. The trainer used in this research was quickly able to demonstrate both his farming and environmental management credentials. He was also independent of the government departments and agencies associated with delivering AES. This may have given him more credibility from the perspective of the farmers.

Having established that the training provided for this research had an impact on techniques, ability and attitudes further work is required to identify the range of options that might be responsive to the training effect and significantly, it will be important to explore the extent to which the impact of training is reflected in environmental outcomes.

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REFEREED REVIEW ARTICLE

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Market driven innovation and entrepreneurial behaviour: The strategic value of a market orientation in primary agriculture

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ABSTRACT

This paper examines the strategic value of a market orientation using concepts from the resource based view of the firm. We show that a market orientation can be a strategic resource as it is heterogeneous, imperfectly mobile, and is imperfectly substitutable. Using examples from both small-scale and large-scale production agriculture, we show how a market orientation can contribute to the awareness and implementation of new processes to improve performance. The paper concludes with a brief discussion of market orientation and firm strategy, along with a discussion of managerial implications and calls for future research.

KEYWORDS: Agriculture; Entrepreneurship; Farmers; Innovation; Market Orientation; Resource Based View

1. Introduction

The agricultural landscape has changed a lot in the past several decades. Across much of the developed world, farm numbers are declining, leaving fewer and larger farms. Evolutionary economics suggests that the farms that remain may be better equipped to meet the challenges of the new environment (Nelson and Winter 1982). Consumers of agricultural products are also changing. Today's customers are demanding food products that possess different attributes (organic, local, natural, etc.) than customers did a generation ago (Pearson, Henryks and Jones 2011; Sims 2009). The combination of these factors means today's farmer faces different challenges and opportunities than those faced by previous generations of agriculturists. Ultimately, for managers of both large and small farms, this may mean that the resources used to build the firm may not be the same resources needed to grow the firm in the future.

Given the changing landscape, one constant is the need for firm-level innovation to meet these challenges. Managers of large and small firms in production agriculture can utilize innovation activities (new products, new processes, new markets, new sources of supply, new organizational structures) to improve performance (Kirzner 1999; Nelson and Winter 1982). However, given the supplier dominated nature of much of primary agriculture, many of the technological innovations are available throughout the industry and therefore cannot deliver long-run superior performance on their own. The duration of the rents from other innovations is dependent upon how appropriable the technology behind the innovation is.

Given increased competition in both local and global markets, success may accrue to those managers that are able to become more innovative and entrepreneurial in their search for profit opportunities. Previous research has shown that innovation occurs due to lack of satisfaction with current performance levels (Bolton 1993) and furthermore, that managers of innovative firms are more satisfied with their performance (Gronum, Verreynne and Kastelle 2012). Similarly, managers of agricultural firms may choose to innovate for personal or financial reasons in order for actual performance to meet or exceed a previously set benchmark or aspiration level (Georgellis, Joyce and Woods 2000; Hessels, Gelderen and Thurik 2008; McGrath *et al.* 1996).

How can managers become more innovative and entrepreneurial? One method that shows some promise is to become more market oriented (Baker and Sinkula 2009). Slater and Narver (1995, p. 67) define a market orientation as 'the culture that (1) places the highest priority on the profitable creation and maintenance of superior customer value while considering the interests

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of other key stakeholders; and (2) provides norms for behaviour regarding the organizational development of and responsiveness to market information.' Therefore, the aim of this paper is to examine if a market orientation is a strategic resource for agricultural managers. Strategic resources are those that allow for the development and maintenance of competitive advantages. For a resource to be strategic, it must be valuable, rare, difficult to imitate, and provide limits to competition (Barney 1991; Peteraf 1993). As farms can compete in a variety of products using several strategies, this paper will examine how a market orientation can be beneficial for small-scale and large-scale operators, and those producers operating in between.

The following section will introduce the concept of a market orientation and discuss its application to production agriculture. Section 3 outlines the characteristics of strategic resources with respect to a market orientation. Section 4 discusses the performance implications of a market orientation and Section 5 shows how a market orientation can be a useful resource for both small-scale and large-scale farms. Section 6 offers some conclusions and suggestions for future research.

2. Market orientation, innovation, and entrepreneurship in agriculture

Alvarez and Busenitz suggest that '…entrepreneurship is about cognition, discovery, pursuing market opportunities, and coordinating knowledge that lead to heterogeneous outputs' (2001, p. 757). Worded differently, this becomes the definition of a market orientation by Jaworski and Kohli (1993). Jaworski and Kohli (1993) state that a market orientation consists of three sets of equally important activities: 1) the generation of market intelligence, 2) the dissemination of this intelligence throughout the firm, and 3) the responsiveness to this new information. Market intelligence comes from observations and interactions with customers and competitors in the agricultural sector, along with observations of trends in other industries that might be applicable to agriculture. For example, some managers have adopted new methods of marketing their production in order to take advantage of changes in consumer tastes and preferences. For example, the value of production being marketed through direct-to-consumer channels in the United States has increased in recent years (Low and Vogel 2011) and may be seen as a way forward for farms in areas undergoing policy transitions (Morgan *et al*. 2010). One possible limiting factor is the use of direct marketing strategies has been shown to be used more often for managers producing high-value crops (Detre *et al*. 2011). This may mean that for firms producing other crops, it may be more difficult to implement these strategies, and the satisfaction with the implementation might be lower.

Managers of firms in commodity markets may choose to adopt innovations that generate efficiency improvements as there is little control over prices received. For example, adopting new technologies may contribute to greater efficiencies, improved yields, and improved revenue for commercial-scale farmers (Nossal and Sheng 2010). For managers of smaller farms, where financial constraints may limit the adoption of new(er) technologies, organizational innovations such as belonging to learning networks and coordinated value chains may improve performance (Bonney *et al*. 2007; Conley and Udry 2001; King *et al*. 2010; Maertens and Barrett 2012; Oreszczyn, Lane and Carr 2010). Managers of smaller farms may find more success with marketing innovations as well as they have more time to identify and react to opportunities than larger farms. Furthermore, managers of smaller farms may have different experiences deriving from off-farm opportunities which can lead the identification and implementation of different organizational and marketing innovations than managers of larger farms (Mishra and Goodwin 1997).

Managers of smaller firms may also choose to adopt innovations in markets served as this may be a better use of their slack resources. In an agricultural context, researchers have examined entrepreneurial actions of farmers in terms of the marketing of new products and services to new and existing customers. A growing literature on farm entrepreneurship has shown that farm diversification is one means that managers use to improve performance (McElwee and Bosworth 2010; Phelan and Sharpley 2012). The degree of diversification can range from small (new crops or livestock) to somewhat great (farm tourism, farm accommodations). Researchers are also examining the effectiveness of business planning initiatives for farms that choose to develop new business models (McElwee and Annibal 2010).

As firms within the same industry may be using different strategies in the pursuit of profit, their needs with respect to innovations and entrepreneurial action may be different. This does not mean, however, that only certain firms may see the value of becoming more market oriented. As commodity markets are relatively stable in terms of consumer preferences, awareness of competitor actions may be more important than awareness of customer trends. Conversely, small-scale firms serving niche markets may find customer awareness to be of considerable importance as the needs of the market are more heterogeneous. In either case, becoming more market oriented may allow firms pursuing very different strategies a greater chance to become aware of opportunities to improve performance through firm-level innovations.

3. The strategic value of a market orientation

It has been suggested that a firm's culture can be considered a resource, in much the same manner as physical or financial assets are considered resources (Barney 1986). In terms of managerial decision-making, it is worthwhile to know if and how different resources contribute to competitive advantages, and if these advantages are sustainable or temporary. As firms can be viewed as a bundle of resources (Penrose 1995) which allow them to pursue different opportunities, the resourced based view of the firm (RBV) may help in determining the strategic value of a market orientation. The RBV literature has closely examined the concept of sustainable competitive advantage and laid out several conditions that a resource has to meet before it can be truly sustainable. Barney (1991) posited that resources need to be valuable, rare, imperfectly imitable and imperfectly substitutable in order to generate sustainable competitive advantages. Peteraf (1993) provides a slightly different definition she claims a resource has to be *heterogeneous*, have *ex post limits to competition*, *imperfect resource mobility*, and *ex ante limits to competition* in order to deliver sustainable advantages to the resource holder. Examining these definitions more closely, we can conclude that they are focusing on the same points as for a resource to have value, not everyone can possess it, which implies heterogeneity and also rareness. Resources that are imperfectly imitable and imperfectly substitutable are those that provide ex post limits to competition.

Previous market orientation studies suggest that the process of building a market orientation lies first in the gathering and dissemination of information by decision makers within the firm, and secondly, and perhaps most importantly, in the reaction to this information in a way that provides value to consumers (Day 1994; Kohli and Jaworski 1990). These studies built upon the work by Porter (1985; 1991) that stated that in order to have continued above-normal performance firms need to create a sustainable competitive advantage. The competitive advantage may stem from differentiation strategies or the ability to produce a commodity-like product more efficiently than competitors may. In either case, the firm had to provide superior value for its customers and had to have some manner in which to protect the advantage from imitation or duplication by rivals.

Resource heterogeneity

Barney (1991) defines a firm's resources to include all assets, capabilities, attributes, information, knowledge, etc. controlled by the firm. These resources can be either physical capital resources, human capital resources, or organizational capital resources. In terms of production agriculture, all of the physical assets available to producers are homogeneous in theory, if not in practice. While the resource endowment can be different across firms, what makes these resources homogeneous is the fact that nearly all actors in the market can easily acquire these resources. While resources developed beyond the farm gate are widely available, human capital resources such as knowledge, intelligence, and experience of the individual manager are heterogeneous as each firm will have a different endowment of these resources. Furthermore, the availability of networks, books, workshops, or extension personnel that may lead to an increased knowledge base will still not cause the level of human capital resource across managers to equalize. Even in instances where access to information is equal, subjective interpretation and application of the specific information will yield a heterogeneous response to this information. Along these same lines, the organizational capital (reporting structure, planning processes, coordination systems, etc.) will also be heterogeneous.

As noted in Narver *et al.* (1998), two principal strategies are needed to develop a market orientation. First, managers need to instil a culture of continuous value creation. Once the culture is in place, they then must develop the resources, capabilities, skills, and knowledge to implement the goal of continuous value creation. This can be thought of in terms of stocks and flows, with the market orientation culture being the stock, and the capabilities, skills, and knowledge acting as the flow (Dierickx and Cool 1989). In agriculture, this flow, along with the underlying asset stock, will likely be heterogeneous in nature. The reason for this is agricultural producers have largely operated as though there is no difference between their product and that of their competitors. Acting as anonymous price takers, producers of crops and livestock have focused on lowering their costs of production in order to develop a competitive advantage. By being one of the early adopters of a new technology that lowers per unit production costs, firms may earn rents as costs have decreased while market prices have yet to reflect this change. In fact, it may be better not to be the first to adopt if there is uncertainty surrounding the technology (Hoppe 2000). Early adopters may find that this advantage may lead to growth of intangible asset stocks such as trust and reputation which may or may not provide a sustainable competitive advantage. However, if the investment was a physical resource, this advantage is likely to be short-lived as others can easily imitate the first-mover and their actions will eventually erode the cost advantage. As posited by Levins and Cochrane (1996), as newer technological or marketing innovations come on-line, the process is repeated (Figure 1).

While the early adopters will have an advantage as their margins have improved, Peteraf (1993) suggests that it is not necessary for only one firm have control over strategic resources in order for there to be positive rent streams. What is important is that these resources are not widespread throughout an industry. In agriculture, some innovative producers have chosen to join production alliances in order to differentiate themselves from the commodity market (Mulrony and Chaddad 2005). These alliances generally differentiate themselves based on the provision of specific attributes in the cattle they market, one being age/source verification. There is value to this information due to its rareness, but once a certain number of producers begin to offer this attribute the pricing mechanism will shift to one of premium pricing for attribute provision to a discount for its

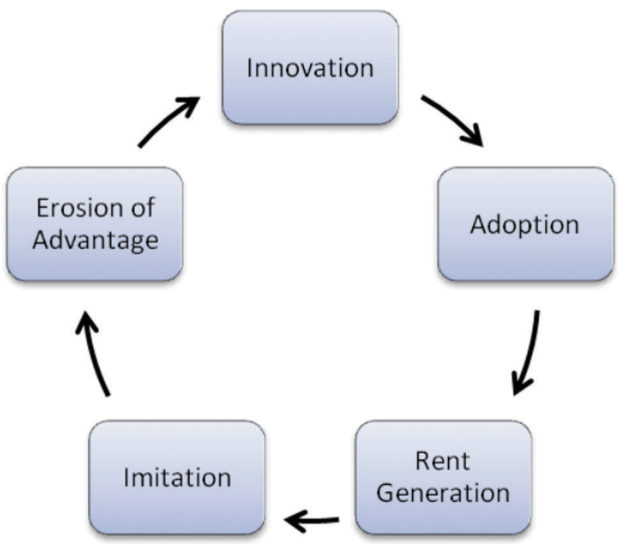

Figure 1: The Innovation Treadmill

absence. As more and more firms follow in their footsteps, the value of the differentiated attribute becomes diluted and competitive parity is the result (Barney 1991). This is not to say that these resources are no longer valuable and therefore they do not provide a sustainable competitive advantage. What has happened is the resource has become less rare and in this case it is the rarity of the resource which creates the value in the marketplace. An agricultural example would be the tractor. Even though tractors are no longer rare, this does not mean that they are no longer valuable.

Ex post limits to competition

Regardless of the nature of the resource, further requirements are needed in order to sustain the advantage into the future. The ability to defend the resource against imitation and substitutability has been recently discussed as a means of providing limits to this competition (Barney 1991; Dierickx and Cool 1989; Peteraf 1993). Once competitors can see that a resource is able to generate positive cash flows, rivals quickly try to acquire the same or comparable resource in order to achieve similar results. An example may be a new, high-yielding variety of wheat that by many producers begin planting in hopes of achieving results similar to that of early adopters. If the firm is not the owner of this new technology, it is impossible for them to prevent rivals from adopting the technology and eroding their advantage. Therefore, in order to maintain their position regarding the rent-generating resource, they must be able to prevent its capture by rivals. Intangible resources such as a market orientation possess characteristics that make them difficult to imitate, such as causal ambiguity, social complexity, and time compression diseconomies.

The ability to imitate the particular resource that generates the rent depends on the characteristics of the resource. Physical resources such as technological advances can be competed away given that similar technologies are available to competitors. This is the case for agricultural technologies developed beyond the farm gate. As the profit function of the developer depends on dissemination of the technology throughout the marketplace, any first-mover advantages will be temporary. The same holds for the developers of the technologies. Even if patent rights protect the resource, competitors could reverse engineer the innovation and develop a product that performs similarly, but somehow falls outside the protection of the patent. A market orientation, while not patentable, provides difficulties in its imitation. Developing a market orientation is not an instantaneous process. One needs to develop a culture that is conducive to the development of a market orientation and then must nurture the resources which are valuable in maintaining the market orientation, namely the market-sensing capabilities that come through relationships, information, and knowledge. Dierickx and Cool (1989) refer to this as time compression diseconomies as building the asset stock of market orientation takes time and experience.

While others may note that a market oriented firm has been receiving higher prices or achieving a greater market share, the ability to observe the development of a market orientation is limited. While one could reverse engineer a recipe through chemical analysis, the development of a market orientation through the same process would be difficult. As an intangible resource, a competitor can not necessarily *observe* the development of a market orientation in the same way one could see a firm develop a tangible resource by examining changes in property, financial statements, or annual reports. Specifically, managers of different firms could have varied interpretations of the value of the underlying assets that build a market orientation (the ingredients in the recipe) such as personnel, knowledge, market information, and communication networks. Even if rivals could see inside market oriented firms, the causal ambiguity involved in building a market orientation 'prevents would-be-imitators from knowing what exactly to imitate or how to go about it' (Peteraf 1993, pp. 182–183).

Provided managers are aware that the source of a competitor's advantage was the development and implementation of a market orientation, there does not seem to be a substitute other than a similar market orientation. In this instance, managers may increase their degree of market orientation in order to try to erode some of the rents created by the initial firm. Imperfect imitability and causal ambiguity would likely attenuate the effectiveness of this process. Though, if imitation indeed was successful, heterogeneity in the application of a market orientation and local economic factors might prevent a total erosion of its value for individual firms. As Slater and Narver (1994) suggest, a market orientation is a valuable resource in any business environment, presumably even one where all firms are market oriented.

Imperfect mobility

Mobility refers to the tradability of a resource under control of a firm. As is understood easily, physical resources are mobile as one firm can sell its plant and equipment to another. What may be imperfectly mobile is the human and organizational capital of a firm. The imperfection lies in the value of the resource within the current firm over and above the value in another firm (Peteraf 1993).

In the case of market orientation, it is difficult to trade the knowledge, brand, reputation and relationships developed for one firm to another. This difficulty is present even with mergers and acquisitions where the acquiring firm incorporates all of the valuable resources of the other firm. In this case, the culture in which the valuable resource was developed is important. While a culture that supported the generation and development of market sensing capabilities may have been present at one firm, this same culture may not be in place at the acquiring firm. As information is stored in the minds of people, not organizational structures, over time personnel may leave, diminishing the stock of the resource. Without increased flow of new market intelligence the firm will become less market oriented.

Even if the flow of market information comes from a public resource, the ability for managers to apply the information in a manner to gain a competitive advantage could be limited. For example, knowledge and innovation brokers who disseminate best practices are becoming more common in agricultural production in both developed and developing economies (Klerkx and Leeuwis 2008; Ortiz 2006). While the presence of such brokers would, in essence, equalize the flow of information across firms, the capabilities of firms which enable managers to transform the flow of information into a resource stock is heterogeneous. Returning to the bathtub metaphor of Dierickx and Cool (1989) heterogeneity in capabilities and culture would be akin to each firm having holes in their bathtub at varying levels. Therefore, even if the managers sell the resource stock to another firm, their ability to maintain that resource, and add to it, may be limited.

Further attenuating the value of the information is that the specific information generated by the individual was relevant to the firm that generated it *at that time and in that market*. Changes in consumers and markets could have occurred which have rendered historical information obsolete. The idiosyncratic nature of market information limits the usefulness of this resource outside of the generating firm (Williamson 1979).

Ex ante limits to competition

The final condition a resource must meet to provide a sustainable competitive advantage is the need for ex ante limits to competition. In this instance, firms cannot reduce the rent available to earn by bidding up the cost of the resource before its deployment. It may help to see this through a counter-example, highly productive farmland. Competing firms are able to determine land quality with some certainty and use their expected returns from farming this land to inform their bidding strategy. Therefore, when high quality land becomes available, managers aware of the land's value bid on the land, increasing the rental rate causing the excess returns to evaporate. Conversely, as a market orientation is both socially complex and causally ambiguous, the ability for firms to bid away advantages stemming from a market orientation is limited.

Social complexity refers to the fact that it might be difficult to determine the valuable source of information used in the intelligence generation process inherent in a market orientation. Market information could come from a variety of sources including university reports, extension bulletins, trade associations, government agencies, visits with channel partners, magazines, or even discussions at the local coffee shop. It would be extremely difficult to increase the cost of these assets as most are public goods and the others would be extremely expensive to adjust. Furthermore, the cost of communication with channel partners is marginal at best, and managers may not even classify this as a cost. As managers can use information from channel partners to improve the farm business in a variety of ways, this would be more appropriately categorized as an investment, not an expense.

4. The performance implications of a market orientation

While the works of Kohli and Jaworski (1990), Narver, and Slater (1990) suggest that market oriented firms enjoy greater performance results, managers cannot simply 'flip a switch' to become more market oriented. A firm can only become market oriented if there is an underlying culture where management and employees are committed to the creation of superior customer value (Narver *et al.* 1998). A market orientation is a culture that is evident through actions that management and employees undertake in the search for value creating opportunities. Those with a desire to become more market oriented must be willing to adopt new routines that enable them to become more proficient at the generation and assimilation of market information as well as becoming more responsive to this information.

While there is some disagreement as to the costs of becoming more market oriented (Harris and Piercy 1997), there are benefits to the successful implementation of a market orientated culture. Studies have shown that developing a market orientation can lead to higher performance measures for the firm across contexts and industries (Tregear 2003; Jimenez-Jimenez and Cegarra-Navarro 2007; Tajeddini *et al.* 2006) and this is based on the ability to quickly sense changes in the market (Day 1994). The ability to generate superior performance implies that managers have the ability to identify consumer needs and develop processes, products and experiences to meet these needs. The ability to acquire, assimilate, and respond to market information faster than rivals may be one of the few sources of sustainable competitive advantage for firms that operate in commodity industries such as production agriculture (Kohli and Jaworski 1990; Slater and Narver 1995). Furthermore, highly market oriented firms may be able to leverage their capability in information generation and responsiveness (Kohli and Jaworski 1990) in the search for and implementation of profit opportunities. It is the ability to develop relationships and build trust with channel partners and customers that allows the firm to create their own source of sustainable competitive advantage for the future.

The ability to become more market oriented is of utmost importance if managers wish to improve performance in an increasingly competitive industry. As suggested by Deshpande, Farley and Webster (1993), the market orientation of a firm is not a binary choice, but a continuum measured by degrees. It may help to think of a market orientation in the same way as one does for other factors of production in that a market orientation directs managers to develop products with certain attributes that meet consumer needs. In this sense, the market orientation of the firm is an asset stock and the information and experience used to maintain the asset is a flow which can be adjusted immediately (Dierickx and Cool 1989).

Regardless of size or strategy pursued, a market orientation may enable managers to be more flexible in their response to changes to market conditions or the competitive landscape. Day (1994) posits that market-driven organizations are better equipped to succeed because they are able to develop relationships with channel partners and customers while maintaining the ability to sense market changes ahead of competitors. These capabilities vary across firms depending on the resource endowment of the asset as well as the strategic decisions regarding the flows used to build the stock of these capabilities. By achieving a high degree of market orientation, managers may be better able to navigate turbulent environments (Achrol 1991) and redeploy or repackage resources to meet changing consumer needs. A market orientation has also been shown to affect the ability for managers to handle a crisis involving high demand uncertainty (Grewal and Tansuhaj 2001). Following the recent cases of food-borne pathogens in beef, spinach and peanut butter, the ability to maintain flexibility through these crises would be a valuable resource to all members of agri-food chains.

5. Application to agriculture

A market orientation is defined as the ability to generate and process information about consumers and competitors while transforming this knowledge into capabilities which are then used to meet consumer needs (Narver and Slater 1990). The process of idiosyncratic information flows building an asset stock leads to heterogeneous levels of market orientation across firms. Heterogeneity results from managers having heterogeneous valuations of customer and competitor information. Further, these resources provide some limits to competition as they are imperfectly imitable due to causal ambiguity, social complexity and imperfect substitutability. Finally, the stock of a market orientation within a firm is imperfectly mobile as it is not easily tradable between firms. This is attributable to the idiosyncratic nature of customer and market information gathered by management within a firm as well as the different interpretations of this information by other managers.

Implications for managers

Extending the work of Johnson *et al.* (2009), Verhees and Meulenberg (2004), and Micheels and Gow (2011), and building on the work of Pelham (1997; 1999) it would be beneficial to further examine the relationship between market orientation and performance in production agriculture. Furthermore, it would help to understand better the process of becoming more market oriented in a sector dominated by relatively homogeneous products. A growing research stream has identified two forms of market orientation, proactive and responsive (Atuahene-Gima, Slater and Olson 2005; Narver, Slater and MacLachlan 2004; Voola and O'Cass 2010). Through further research, authors could examine exactly what it is that makes market oriented firms different from less market oriented counterparts, and if certain contexts are more conducive to different forms of market orientation. For example, many large-scale agricultural producers are well informed when it comes to new technologies that increase productive efficiency as they compete in a globalized market with established grades and standards for their production. Conversely, small-scale producers may pay more attention to the customer as in localized markets, standards may be more fluid due to changing tastes and preferences and therefore they may be able to leverage their flexibility to differentiate their processes in order to satisfy this demand. It may be, therefore, that a responsive market orientation is better suited to large-scale operations whereas a more proactive approach would be beneficial for smaller operations. In either case, the underlying market orientation may be a resource that managers can use to understand factors both inside and outside the farm gate that affect the performance of their firm.

As agricultural production becomes increasingly competitive and consumers become more discerning, the value of a market orientation may only increase. In his study, Pelham (1999) found the relationship between market orientation and performance to be strongest in differentiated markets. Judging from the increase in the use of brands to try to differentiate production, one could conclude that the agricultural marketplace is becoming increasingly segmented. Even the global beef trade is becoming more segmented as beef is marketed based on feeding and management practices as well as the use (or lack thereof) of growth hormones (Quilty 2013). At a much smaller scale, as farmers markets and community supported agriculture (CSA) operations grow in popularity, market segmentation seems to be increasing across a variety of agricultural products.

Depending on how managers of agricultural firms provide value to the market, the degree of market orientation could have significant impacts. Treacy and Wiersema (1993, p. 91) state that 'becoming an industry leader requires a company to choose a value discipline that takes into account its capabilities and culture as well as competitors' strengths.' Managers may choose to provide value based on the degree of innovation (product leadership), B2B or B2C relationships (customer intimacy), or production efficiency (operational excellence). The market-sensing capabilities of the firm are extremely important if they choose to operate in the customer intimacy or product leadership disciplines.

In this manner, small-scale operations may develop a customer intimacy strategy where they attempt to differentiate their production by eliminating intermediaries and marketing products directly to the consumer. This may result in better margins for farmers (Guthrie *et al.* 2006) while also leading to reduced information asymmetries for customers (which can be used as a basis for further product or process innovation). As competing on price may be better suited for firms with greater economies of scale, smaller firms may find it beneficial to compete within a customer intimacy discipline after analysing where their comparative advantage lies. In this setting, a strong market orientation could be a significant source of competitive advantage. It would allow small firms, who do not have the scale to be the low-cost producer or the research budget to be product innovators, to compete by meeting the needs of specific customers through increased flexibility, responsiveness and adaptability. Furthermore, as smaller firms may be more likely to diversify their operations, a market orientation may improve the success of these ventures relative to those of less market oriented firms.

Large-scale operations may have a wider variety of options. In output markets, they can leverage their scale to make better use of new production technologies that improve yields and lower costs of production. As cost is sometimes a barrier to the adoption of new technologies, scale effects may allow larger farms to spread these costs over a larger land base, thereby lowering the per-unit costs. This may not be economical or even possible for small-scale operations. In the input markets, large-scale farms may find that a market orientation may enable them to develop a customer intimacy strategy for dealing with numerous landlords. As rising farmland values make it difficult to own all the land that one operates, managing the landlord-tenant relationship is an important aspect of many large farms. A customer intimacy strategy may enable operators to develop better relationships with their landlords and thereby increase the probability that the relationship will continue. This may be a risk-reducing strategy for both owners and operators as resource allocations by the farmer may be affected by the expected probability that they will farm a parcel of land during the next year.

6. Conclusions and future research

In this paper we have suggested that a market orientation provides a source of sustainable competitive advantage for firms in production agriculture. Using the framework developed by Barney (1991) and Peteraf (1993), we illustrated that a market orientation can provide sustainable competitive advantages to agricultural firms. We then showed how managers of both large and small firms can apply a market orientation to their operations. Combining the market orientation and value discipline literatures, we further demonstrated how managers could use a market orientation to develop and implement specific strategies that may improve performance on their farms.

While this paper showed that a market orientation may provide sustainable competitive advantages, further research that focuses on the measurement and consequences of a market orientation of agricultural producers and value chains would benefit both academics and practitioners, especially in terms of how market orientation influences firm performance. Directions for future research should include the examination of proactive and responsive market orientations and the contexts in which each is superior. As an anonymous reviewer has suggested, it would be also worthwhile to quantify the costs and benefits of becoming market oriented. Then managers can make better informed decisions on the value of investing resources on becoming more market oriented.

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Production constraints and their causes in the cacao industry in West Sumatra: from the farmers' perspective

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ABSTRACT

We use structural equation modelling to conduct a path analysis for cacao production in West Sumatra, Indonesia, quantifying the main constraints identified by farmers attempting to increase their incomes. Stakeholders in a workshop identified low yield of cacao trees and low quality of cacao beans as the two main production constraints, which are the focus of this study. Farm-level data from 100 smallholders were analysed to describe and estimate the dependencies between various factors and their relationship to farmers' income. Five variables – source of cacao seedlings, expenditure on pest and disease management, expenditure on fertilizer, frequency of pruning, and pest and disease attack – were hypothesized to influence the yield of cacao trees. Yet farmers considered only fertilizer expenditure to have the expected positive influence. They considered lack of capital to be a critical factor indirectly impeding fertilizing practices. Expectations that farmers would perceive that the quality of their cacao beans and their ability to bargain would affect the price they received proved incorrect.

KEYWORDS: cacao farming; path analysis; production constraints; West Sumatra

1. Introduction

This paper presents results of an empirical analysis to identify the factors perceived by farmers in West Sumatra to influence their production of cacao. The aim of the analysis is to assess the effects of these factors on the gross incomes of these farmers. The views of farmers, particularly on complex cause-and-effect relationships, are often difficult to elicit in workshops in which other stakeholders participate. To overcome this limitation, a path analysis framework was adopted to determine the main constraints facing farmers. A cause-and-effect model within this framework was drawn initially as a problem tree in workshops. The structural equations method was then used to assess cause-and-effect relationships among the variables in the model.

Cacao is one of the estate commodities that play an important role in export earnings and employment opportunities in Indonesia. It ranks fourth in value among Indonesian export commodities. Indonesia contributed 15 per cent to total world cacao output in 2009/2010 and continued to be the third largest cacao producer in the world in 2011/2012 (ICCO, 2012). Cacao farming is the main source of income for more than one million smallholder farmers who own 94 per cent of the total cacao area. Cacao is planted throughout Indonesia, with Sulawesi producing 66 per cent of the national cacao output. Even though the output share of West Sumatra is much less than Sulawesi, it had the highest annual growth rate among the top ten cacao areas in the period 2004–2009. The share of cacao area to total estate crops area in this province increased six-fold during this period. Cacao area is expected to increase further in West Sumatra due to continuing government support programs to develop cacao-coconut intercropping farming systems. Due to the industry's importance to the economy and the role of smallholders in it, there is the potential for the industry to play an important role in poverty alleviation.

Some analysts (e.g. ACDI/VOCA, 2005; Akiyama and Nishio, 1997; Badcock, Matlick and Baon, 2007) noted that Indonesia's cacao industry has a comparative advantage in producing cacao beans due to low real costs, high productive capacity, efficient infrastructure and an open marketing system. This comparative advantage, however, has been threatened by a number of problems in production and marketing. ACDI/VOCA (2005), Handayane (2007) and Sahara, Dahya and Syam (2005) found that cacao yields in Indonesia could not achieve their potential. Improper use of fertilizer was identified as a cause of low production, while pests and diseases were thought to contribute to problems of low production and low quality. Improper fermentation was identified as another cause of low quality of cacao beans based on research by ACDI/VOCA (2005) and Handayane (2007). Other shortcomings have been observed that are marketing problems facing Indonesian cacao farmers. They include

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weak bargaining position, lack of access to financial support and receiving a less remunerative price for fermented cacao beans (Djajusman, 2007). In order to develop the cacao industry in West Sumatra, the study aims to identify the factors limiting development and establish priority areas for action.

Attempts by government agencies to develop the cacao industry have confronted complex issues. Although the industry should be viewed as a system that includes production, marketing and institutional aspects, the analysis and discussion in this paper is limited to production. We cover agronomic practices, post-harvest practices and access by farmers to resources.

Data collection is discussed in the next section, and is followed by an explanation of the use of path analysis in model estimation in the third section. Results are discussed in the fourth section and the paper ends with concluding remarks.

2. Data collection

The study was conducted in West Sumatra province for two reasons. First, West Sumatra is designated as the production centre for cacao in Western Indonesia. Second, cacao development in this province is mainly funded by the provincial and regency governments, indicating their strong interest in developing the cacao industry. Three municipalities are involved in this study–Pasaman, 50 Kota and Solok–which were selected based on their distance to the export point. Solok is located close to the major provincial city and market of Padang; Pasaman is remote from Padang; and 50 Kota is located between these two spatial extremes.

Participatory impact pathway analysis (PIPA) workshops were conducted in the three municipalities at the initial stage of the study, which involved cacao industry stakeholders. It is now widely accepted that all stakeholders should have a voice in formulating and implementing government agricultural projects and programs (see Devendra, 2007; Grimble and Wellard, 1997; OED ADB, 2004). PIPA, propounded by Douthwaite *et al.* (2007; 2008), offers a method to achieve this goal, which is 'a practical planning, and monitoring and evaluation approach developed for use with complex projects in the water and food sectors' (Douthwaite *et al.*, 2008, p. 1). It engages an action research process based on impact pathways and contains a set of detailed assumptions and hypotheses that lead to the development of a set of strategies for a project to achieve its goals. These pathways describe normative actions by individuals and organizations for change, and how such change might influence the livelihoods of people (Douthwaite *et al.*, 2008). A fundamental component of the approach is the formulation of a problem tree to identify constraints to development. A shortcoming of PIPA is its inability to quantify and prioritize relationships in the problem tree from a stakeholder perspective. The ability to do this will lead to a better understanding of the relative importance of the different constraints encountered along each 'branch of the tree' or pathway.

The PIPA workshop enabled the cause-and-effect model to be drawn in the form of a problem tree as the basis for path analysis. Participants in the PIPA workshop identified low yields and low quality of cacao beans as the main problems constraining farmers from increasing their incomes. These problems were confirmed through surveys conducted in the three municipalities. Data were collected by interviewing a random sample of 100 heads of farm households using a structured questionnaire from September 2009 to March 2011. The information was gathered in relation to the period from June 2009 to May 2010.

The surveys identified a number of factors that were influencing cacao yield and quality in the cacao industry in West Sumatra. The path analysis method was employed to incorporate these factors as constraints facing farmers in model estimation, which is discussed in the next section.

3. Application of path analysis to cacao production

Path analysis is a method to interpret and decompose correlations among variables in linear causal models (Burridge and Schwabe, 1977; Kingsolver and Schemske, 1991). It is considered to be complementary to the PIPA approach. While PIPA focuses on constructing a problem tree and the use of qualitative data, path modelling allows data to be analysed quantitatively based on the problem tree.

Path analysis is a specific structural equation modelling (SEM) approach that represents hypotheses about effect priority by involving observed variables (Kline, 2011; Wolfle, 1980). It is also known as causal modelling which is often drawn in the form of path diagrams with the advantage of a visual presentation of a complex argument (Biddle and Marlin, 1987; Li, 1975).

The construction of models used in path analysis is based on the algebraic manipulation of standardized unidirectional path coefficients in systems of variables (Wright, 1965). This method works by applying prior knowledge that is constructed in the form of a diagram with an assumption of linear relationships among variables (Iriondo, Albert and Escudero, 2003; Kingsolver and Schemske, 1991). Correlation coefficients and regression analysis are used to model more complex relationships among observed variables (Schumacker and Lomax, 2004), improving the rationale of conventional regression calculations (Duncan, 1966).

Causal models inspired the development of SEM (Biddle and Marlin, 1987) through its integration with a confirmatory factor model (Schumacker and Lomax, 2004). Grace (2006, p. 10) defined SEM as 'the use of two or more structural equations to model multivariate relationships'. Poon (2007) suggested SEM as an approach that can be used to verify substantive theories that is also applicable to estimate a model that involves various types of data. Many analysts have referred to SEM as a mathematical tool for drawing causal conclusions from a combination of observational data and theoretical assumptions (Pearl, 2011). Barrett (2007) referred to SEM as a modelling tool that fits models to data, making model testing an important requirement to determine the fit of a model to data when using SEM.

Schumacker and Lomax (2004) pointed out some advantages of SEM as a method to test complex phenomena. Greater recognition is given to the validity and reliability of observed scores from measurement instruments. It treats the measurement error and statistical analysis of data separately. It is also able to analyse multi-group and multi-level variables.

The issue of causality is an important arena of debate among analysts. Sobel (2008) argued that structural parameters should not be interpreted as effect. His argument was supported by Biddle and Marlin (1987) and Shipley (1999). Biddle and Marlin (1987 stated that the SEM technique provides only associational or temporal relations among variables. They asserted that it cannot provide sufficient evidence to show the causal relations that some users claim and consequently misinterpret the results. This is the reason why some analysts, as listed by Pearl (2011), try to avoid the term, causality, by referring to covariance structure, regression analysis or simultaneous equations. However, Pearl noted that causal effect can be estimated from data without bias when all causal factors are estimable. Grace (2006) noted some arguments against the causal interpretation of SEM but also argued that it can support the argument for causal interpretation if it is built on the complete body of available knowledge. Biddle and Marlin (1987) provided several criteria to judge the success of SEM to confirm a causal model. They consist of the amount of variance explained in intervening and dependent variables, the significance of path coefficients in a path diagram, the relative sizes of regression coefficients, capturing paths by intervening variables, the significance of measures of fit, the significance of covariance among disturbances, model comparisons and sample comparisons. Kelloway (1995) suggested that SEM can provide a causal inference if the temporal ordering of variables is demonstrated and all relevant causes have been incorporated. The application of statistical relationships to causal interpretation has frequented the social sciences literature since the 1960s and the ecological literature since the 1970s.

There are several applications of SEM in the social sciences. Pajares and Miller (1994) used path analysis to test the predictive and meditational role of self-efficacy beliefs in mathematical problem solving. They stated that path analysis is appropriate in an investigation when social cognitive theory and previous findings have strong theoretical and empirical support for the hypothesized relationships. Cziráky *et al.* (2006) considered the use of SEM as a stand-alone analytical method to be applicable for regional development assessment, but argued that the methodological approach is enriched when combining the application of SEM with non-parametric classification methods such as cluster analysis. Hunn and Heath (2011) used path analysis to assess the causal relationship between life circumstances and depression, and their sequential effects on employment and welfare use. Lee, Weaver and Hrostowski (2011) used it to construct a conceptual model of the effect of the work environment and psychological empowerment on worker outcomes in public child welfare. Arsyad and Kawamura (2009) used it to assess their poverty causal model of cocoa smallholders in Indonesia. Said and Sallatu (2004) used it to construct a structural causal model for poverty incidence. SEM was used by Christensen *et al.* (1999) to assess the effects of age on anxiety and depression, and to examine whether age has direct effects on self-reporting of individual symptoms.

The SEM approach has also been applied in other disciplines such as environmental science (Leduc *et al.*, 1992), tourism (Gursoy, Jurowski and Uysal, 2002) and agricultural research (Asghari-Zakaria, Fathi and Hasan-Panah, 2007; Dalkani, Darvishzadeh and Hassani, 2011; Das *et al.*, 2010; Gantayat and Pattnaik, 2010; Iriondo *et al.*, 2003).

Path analysis is used in this study for four reasons. First, as indicated above it is a method to explore cause-and-effect relationships among variables in a complex system if underlying theory establishes a sound basis to expect causal relationships to be present. Second, all variables in the model are observed variables, which is one of the characteristics of path modelling. Third, path analysis provides the decomposition of the effects of variables that enables us to assess the indirect effects of exogenous variables on endogenous variables that are transmitted through intervening variables. Fourth, correlations among the variables can be estimated simultaneously.

Model specification

Path analysis begins with an initial structural equation model that is formulated on prior information. At this stage, relationships are specified to decide which variables causally affect other variables. Variables involved in path analysis are called measured variables because they are directly measured representing the data; they are also called observed or manifest variables. The measured variables can be categorical, ordinal or continuous (Kline, 2011).

Independent, intervening and dependent variables are also used in path analysis. The relationship between a dependent variable and a set of determinant (independent and intervening) variables can be represented by the generalized univariate statistical formula (Grace, 2006):

$$y_i = \alpha_i + \mathrm{BX} + \varepsilon_i \quad (1)$$

where y_i refers to an observed dependent variable, α_i represents an intercept, **X** refers to a vector of determinant variables, **B** represents a corresponding vector of coefficients (βs) that empirically link y_i to the elements in **X**, and the ε_i represent random errors associated with the i^{th} dependent variable. Equation (1) can be classified as a structural equation (Grace, 2006).

The relationships among variables in SEM can be visualized with a diagram (Kline, 2011) in which observed variables are represented with squares or rectangles and latent variables are represented with circles or ellipses. A line with a single arrowhead, which relates one variable to another, represents the hypothesized directional effect. Covariance between independent variables is drawn as a curved line with two arrowheads.

The base model for cacao production in West Sumatra is derived from the problem tree generated in the PIPA workshop, illustrated in Figure 1. It captures the perceptions by workshop participants about the

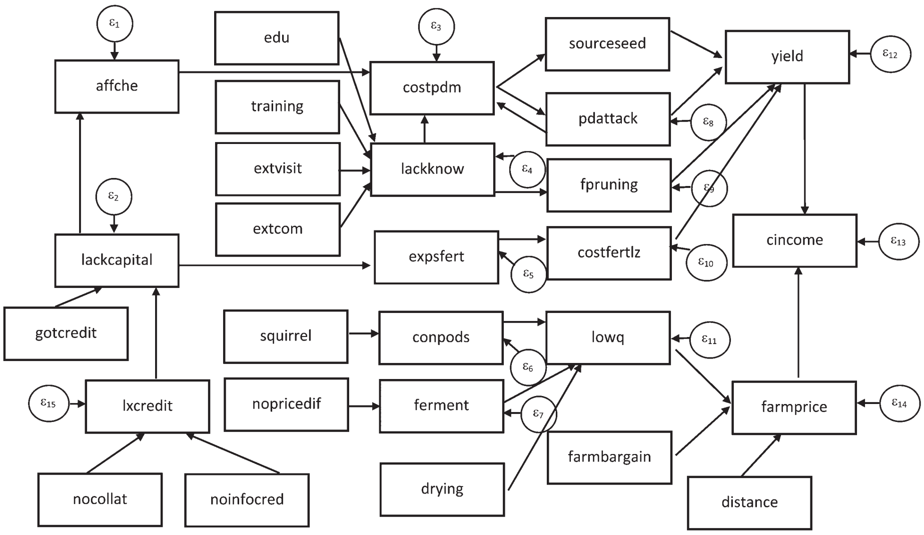

Figure 1: Base model for cacao production in West Sumatra

effects of changes in cacao production performance on the gross income of cacao farmers.

All variables in the model in Figure 1 are drawn with a rectangle because they are observed variables. Errors are drawn in circles because they are latent variables. The model is non-recursive because it has a direct feedback loop between variables *pdattack* (pest and disease attack on cacao trees) and *costpdm* (total cost of chemicals to control pest and disease). The reciprocal relation between these two variables is built on two assumptions. First, farmers may manage pest and disease for prevention purposes. Thus, pest and disease management activity can reduce pest and disease attack. Second, farmers may initiate pest and disease management when they face pest and disease attack. In this case, pest and disease attack influences pest and disease management activity.

Cacao income is at the end of the pathways in the model, measured as revenue from selling cacao beans. Even though the magnitude of the relationship between yield and farm income is known, the involvement of farm income in the model is for completeness to show the pathways from production performance to the economic condition of farmers.

Cacao income from the previous year may affect farmers' ability to obtain credit and thus be an indicator of lack of capital. This presumption allows us to connect *cincome* (cocoa gross income) to *gotcredit* (obtained credit in the past two years) and *lackcapital* (lack of capital) in the model. However, the correlation of those variables cannot be explored in this study due to the unavailability of data on cacao income in the previous year. In the model, the variable *nocollat* (lack of access to credit due to no collateral) is intended to capture a farmer's ability to obtain access to credit.

The variable in the model, *farmprice*, is the cacao price received by individual farmers. Tomek and Robinson (2003) stated that the price of a product is influenced by market structure, which is characterised by numbers of buyers and sellers, distribution size and the degree of product differentiation. The market structure for cacao beans in Indonesia is considered to be competitive because large numbers of farmers and buyers are involved in marketing without government intervention. The cacao value chain is characterised by individual transactions between sellers and buyers. At the farm level, individual transactions occur between farmers and two forms of marketing intermediaries: village buyers and wholesalers. Tomek and Robinson (2003) observed that unique attributes such as variation in quality of individual lots, different locations, differing terms of trade and imperfect information can generate price differentiation in individual transactions at any time. This issue is reflected in variable farm prices in this study to capture variations in individual farm-gate prices of cacao beans.

The system presented in Figure 1 can be written as 15 structural equations. Equations (2) to (6), equations (9) to (11) and equation (16) describe factors contributing to the yield of cacao beans. Equations (7), (8) and (12) formulate factors affecting the quality of cacao beans. Equations (13) to (15) relate to factors affecting the gross income of cacao farmers.

$$affche = \alpha_1 + \beta_1\, lackcapital + \varepsilon_1 \quad (2)$$

$$lackcapital = \alpha_2 - \beta_{21}\, lxcredit + \beta_{22}\, gotcredit + \varepsilon_2 \quad (3)$$

$$costpdm = \alpha_3 - \beta_{31}\, affche + \beta_{32}\, lackknow + \beta_{33}\, pdattack + \varepsilon_3 \quad (4)$$

$$lackknow = \alpha_4 - \beta_{41}\, edu + \beta_{42}\, training + \beta_{43}\, extvisit + \beta_{44}\, extcom + \varepsilon_4 \quad (5)$$

$$expsfert = \alpha_5 + \beta_5\, lackcapital + \varepsilon_5 \quad (6)$$

$$condpods = \alpha_6 + \beta_6\, squirrel + \varepsilon_6 \quad (7)$$

$$ferment = \alpha_7 + \beta_7\, nopricedif + \varepsilon_7 \quad (8)$$

$$pdattack = \alpha_8 + \beta_8\, costpdm + \varepsilon_8 \quad (9)$$

$$fpruning = \alpha_9 + \beta_9\, lackknow + \varepsilon_9 \quad (10)$$

$$costfertlz = \alpha_{10} + \beta_{10}\, expsfert + \varepsilon_{10} \quad (11)$$

$$lowq = \alpha_{11} + \beta_{111}\, condpods + \beta_{112} ferment + \beta_{113}\, drying + \varepsilon_{11} \quad (12)$$

$$yield = \alpha_{12} + \beta_{121}\, sourceseed + \beta_{122}\, costpdm + \beta_{123}\, pdattack + \beta_{124} fpruning + \beta_{125}\, costfertlz + \varepsilon_{12} \quad (13)$$

$$cincome = \alpha_{13} + \beta_{131}\, yield + \beta_{132} farmprice + \varepsilon_{13} \quad (14)$$

$$farmprice = \alpha_{14} - \beta_{141}\, lowq + \beta_{142} farmbargain + \beta_{143}\, distance + \varepsilon_{14} \quad (15)$$

$$lxcredit = \alpha_{15} - \beta_{151}\, nocollat + \beta_{152}\, noinfocrd + \varepsilon_{15} \quad (16)$$

where:

α_i refers to the intercept associated with the i^{th} dependent variable

i is the first subscript to identify the dependent variable in the equation, which has a value of 1, 2, 3, …

β_{ij} represents the path coefficient that links the i^{th} dependent variable and the j^{th} independent variable

j is the second subscript to identify the variable that has a direct effect on the dependent variable in the equation, which has a value of 1, 2, 3, …

The 26 measured variables consist of dependent, independent and intervening variables (Table 1). An independent variable in an equation can be a dependent variable in another. For example, *lackcapital* is a dependent variable in equation (3) while it is an independent variable in equation (6). Path analysis enables us to assess the effect of *lxcredit* (lack of access to credit) and *gotcredit* (obtained credit in the past two years) on *affche* (affordability to buy chemicals) that is transmitted through the variable *lackcapital* as an intervening variable in the model. The effect of all variables in the model on the income of cacao farmers, in turn, can be assessed simultaneously. This effect is discussed when interpreting the results. The next step in path analysis is to estimate the base model.

Estimation results

The path model of the cacao industry in West Sumatra was estimated using *Stata* Version 12 (StataCorp, 2011). The extent of multicollinearity in the model was measured using the variation inflation factor (VIF). A model is considered to have high multicollinearity when the value of VIF is greater than 10 (El-Dereny and Rashwan, 2011) or the correlation coefficient among the exogenous variables is greater than 0.9 (Grewal, Cote and Baumgartner, 2004). *Stata* results show that VIF values for all variables in the model are below 2, indicating that multicollinearity is not a problem in the model.

Before interpreting the results of the path analysis, the original model was assessed to determine whether it adequately fits the data. The goodness of fit of the model was tested using the root mean squared error of approximation (RMSEA), comparative fit index (CFI) and Tucker Lewis index (TLI). Many SEM analysts (e.g. Bayard and Jolly, 2007; Cai, Jun and Yang, 2010; Chi and Qu, 2008) have used these indices to assess model fit.

According to Kline (2011), RMSEA is scaled as a badness-of-fit index and follows the theory of a non-central chi-squared distribution. Its value is sensitive to degrees of freedom and sample size. The greater the degrees of freedom and the larger the sample size, the smaller the value of RMSEA is, where a zero value of RMSEA indicates the best fit and a value$\leq$0.05 indicates a good fit. To assess a model as having a good fit, the values have to be$\leq$0.05 for the lower bound (close-fit hypothesis) and$<$0.10 for the upper bound (poor-fit hypothesis). Streiner (2006) categorized values of RMSEA over 0.10 as a bad fit, values less than 0.08 as a reasonable fit, and values less than or equal to 0.05 as a good fit.

CFI is an incremental fit index that compares a model with a statistical baseline model (Kline, 2011). Its values range between 0 and 1, and a value$>$0.90 indicates a good fit of the model (Feldman and Bolino, 1999; Lester, 2009; StataCorp, 2011). Many analysts (e.g. Feldman and Bolino, 1999; Iriondo *et al*., 2003; Mulaik, 2009) noted that CFI is more reliable to assess the model fit for a small sample because it is not sensitive to sample size. TLI includes a correction for model complexity. A model is considered well-fitting if the TLI value is greater than 0.9 (Chi and Qu, 2008).

Values of fit statistics for the base model indicated that it was a poor fit according to the CFI (0.750), TLI (0.721) and the RMSEA test (0.096). To improve the goodness of fit, the model needed to be modified by removing insignificant variables and eliminating paths from the model (model trimming) or by building some more paths in the model (model building). Model trimming is done by constraining free paths to zero. Model building is done by specifying previous zero paths as free parameters. The aim of trimming and building models is to find a good model that fits the data, and can be justified on theoretical grounds Kline (2011).

Some of the estimated coefficients in the initial model were insignificant. There are two categories of insignificant variables: (1) those that do not have a significant relationship with all other variables; and (2) those that do not have a significant relationship with some variables while correlating significantly with other variables. The variables in the first category are *gotcredit*, *edu*, *extvisit*, e*xtcom*, *sourcesee*d, *cotspdm*, *pdattack*, *fpruning* and *farmbargain*. The variables in the second category consist of *affche*, *lackknow*, *lowq*, *condpods* and *ferment*. At the model modification stage, the variables in the first category were considered for removal from the model while those in the second category remained in the model.

In model trimming, six variables (*gotcredit*, *edu*, *extvisit*, e*xtcom*, *costpdm* and *fpruning*) in the first

Table 1: Description of variables in the path model of cacao production

Variable	Description	Unit
cincome	Farmer's gross income from cacao farming per hectare per year.	Rupiah
yield	Total quantity of cacao beans per hectare per year.	Kilogram
farmprice	Price of cacao beans received by farmers.	Rupiah/kg
sourceseed	Source of seedling farmers got for cacao farming.	2=from government program 1=other source
pdattack	Pest and disease attack on cacao trees.	2=yes; 1=no
fpruning	Frequency of pruning cacao trees per year.	2=yes; 1=no
costfertlz	Total cost of fertilizer per year.	2=yes; 1=no
expsfert	Reason for not fertilizing cacao trees.	2=expensive fertilize; 1=otherwise
costpdm	Total cost of chemicals to control pest and disease per year.	2=yes; 1=no
affche	Reason for not managing pest and disease.	2=cannot afford to buy chemicals; 1=otherwise
lackknow	Farmers are lack of knowledge on agronomic practices.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
edu	Years of educational attainment	years
training	Got training in the past 5 years	2=yes; 1=no
extvisit	Frequency of visits by extension officers per year.	Frequency of visits per year
extcom	Communicating with extension officer.	1=never; 2=sometimes; 3=often; 4=every visit
lackcapital	Farmers face lack of capital	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
gotcredit	Got credit in the past 2 years	2=yes; 1=no
lxcredit	Lack of access to credit	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
nocollat	Lack of access to credit due to no collateral.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
noinfocrd	Lack of access to credit due to not enough information on credit.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
lowq	The quality of cacao beans is low.	1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree
condpods	Condition of pods harvested.	1=partially ripe; 2=mix of partially and fully ripe; 3=fully ripe
ferment	Number of days for fermenting cacao beans per activity.	Number of days
drying	Number of days for drying cacao beans per activity.	Number of days
squirrel	Reason for not harvesting fully ripe pods.	2=squirrel attack; 1=otherwise
nopricedif	Reason for not fermenting cacao beans.	2=no price difference; 1=otherwise
farmbargain	Ability of farmers to bargain on price of cacao beans.	1=no; 2=yes
distance	Distance of farmers' location to export point.	kilometre

category were removed. Removing *pdmanag* and *pruning* left variables *lackknow*, *training* and *affche* unconnected in the whole model; therefore, these three variables were also removed. Even though the effects of *sourceseed*, *pdattack* and *farmbargain* were not significant, they were remained in the model because the coefficients of *sourceseed* and *pdattack* have expected signs and removing *farmbargain* from the model contributed to worse model fit.

The resulting model had a better fit to the data than the base model with the CFI, TLI and RMSEA values of 0.910, 0.896 and 0.087, respectively. Even though the CFI value indicates a good fit, the other two fit tests indicate poor fit. Therefore, another round of modification was undertaken.

The second modification in building the model was conducted based on a modification indices test. StataCorp (2011) referred to modification indices as score tests (Lagrange multiplier tests) for the statistical significance of the omitted paths. They provide a suggestion for an additional path to improve the goodness of fit of a model. If a path with a high value of modification index is added to the model, it can generate a large improvement in overall fit (Kline, 2011, p. 217).

Many additional paths were suggested by the modification indices test to improve the model fit, but some did not make sense from a theoretical perspective. Therefore, only paths supported by theory were considered to be added in the model. Paths added to the model on the basis of the modification indices test were the paths from *distance* to *ferment* and *fertlz*, from *lackcapital* to *fertlz*, from *pdattack* to *condpods*, and from *farmbargain* to *condpods.* As the relationship between *expsfertl* and *costfertlz* was not significant, the variable *expsfertl* was removed from the model.

The second modification generated the final model, which is illustrated in Figure 2. The numbers near the arrows are path coefficients between the variables, while error values are located close to the error terms. Intercepts are written in the rectangles. Based on the model fit index test, it provides a satisfactory fit and is used for further analysis. The CFI, TLI and RMSEA values are 0.941, 0.928 and 0.070, respectively.

4. Interpretation of results

Model coefficients and their significance

For the purpose of comparing the predictive power of the predictor variables, the estimation result should be presented in the form of standardized coefficients. Kline (2011) noted that unstandardized regression coefficients cannot be used to compare the effect of predictor

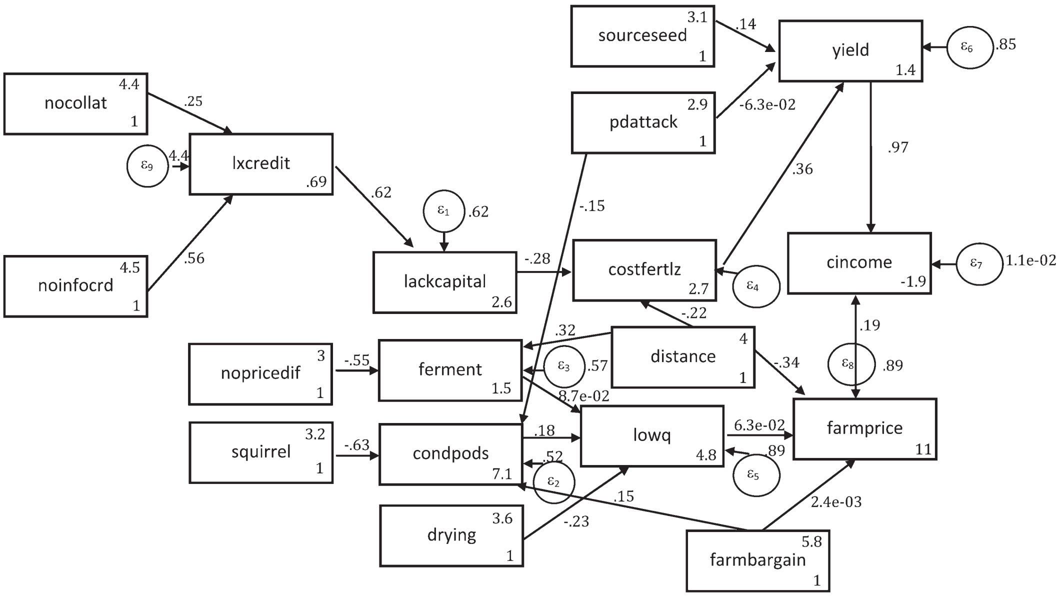

Figure 2: Final model for a path analysis of cacao production

variables in the model because they reflect the scales of their respective predictors with different raw score metrics. The standardized path coefficients of the causal model for cacao production are presented in Table 2.

Of all the path coefficients from the determinant variables to yield of cacao trees, only that from *costfertlz* (β=0.36, z=4.15) is significant at the 0.05 level, whereas *sourceseed* (the source of seedlings) and *pdattack* do not have significant effects. This figure indicates that the higher the farmers' spending on fertilizers the higher the yield of cacao trees.

Fertilizing practices play an important role in increasing the yield of cacao beans, yet about 31 per cent of sample farmers did not fertilize their cacao trees. Distance of farmers' location to export point and lack of capital are two factors significantly influencing farmers' fertilizing practices. Farmers located close to the export point (the capital city of West Sumatra) spent more on

Table 2: Maximum likelihood estimation of the final model

Endogenous variable	Exogenous variable	Standardized path coefficient	z-value
lackcapital	*lxcredit*	0.618*	10.31
	constant	2.597*	5.31
costfertlz	*lackcapital*	−0.282*	−2.99
	distance	−0.216*	−2.27
	constant	2.725*	5.64
condpods	*squirrel*	−0.628*	−11.84
	pdattack	−0.150*	−2.06
	farmbargain	0.148*	2.07
	constant	7.132*	11.86
ferment	*nopricedif*	−0.552*	−9.36
	distance	0.317*	4.48
	constant	1.499*	3.72
lowq	*ferment*	0.087	0.92
	condpods	0.181*	1.90
	drying	−0.229*	−2.47
	constant	4.791*	6.13
yield	*costfertlz*	0.362	4.15
	sourceseed	0.140	1.52
	pdattack	−0.063	−0.68
	constant	1.367*	3.29
farmprice	*Lowq*	0.063	0.67
	farmbargain	0.002	0.03
	distance	−0.338*	−3.93
	constant	11.140*	11.02
cincome	*farmprice*	0.189*	8.88
	yield	0.972*	169.35
	constant	−1.853*	−11.27
lxcredit	*nocollat*	0.248*	2.90
	noinfocrd	0.563*	7.32
	constant	0.692*	1.89

*significant at α=0.05 using a one-tail test.

fertilizers than remotely located farmers (β=−0.27, z=−3.15). This may relate to the survey result revealing that the price of inorganic fertilizer in remote locations was more expensive as a result of the higher cost to transport inorganic fertilizer to these locations.

In a previous study, Agbeniyi, Ogunlade and Oluyole (2010) found that economic constraint and unavailability of fertilizer were cited as the main reasons for not using fertilizers. 'Fertilizer is expensive', the main reason given for not fertilizing in this study, corresponds to the economic constraint reason observed by Agbeniyi *et al.* (2010), who suggested that the introduction of cacao pod husk fertilizer would be a solution to encourage farmers to fertilize their cacao trees.

In the workshop, farmers identified lack of capital as a constraint to the use of fertilizers. Model results reported in Table 2 reveal a significant negative relationship between these variables, with a standardized path coefficient of −0.282 (z=−2.99). This estimate implies that farmers who lack capital spend less on fertilizers.

Lack of access to credit was perceived by farmers to cause their lack of capital. The relationship between these variables was found to be significant and positive with a standardized path coefficient of 0.62 (z=10.31). Many studies (e.g. Ahluwalia, 1990; Bhutto and Bazmi, 2007; Coughlin, 2011; Debroy, 2004; Dorward *et al.*, 2004) confirm this result, finding that lack of access to credit is a major cause of lack of capital facing small farmers.

There are two factors affecting lack of access to credit (*lxcredit*) in the cacao industry: lack of collateral (*nocollat*) and lack of information on credit (*noinfocrd*). These two factors are significantly correlated to lack of access to credit with standardized path coefficients for *nocollat* and *noinfocrd* of 0.25 (z=2.90) and 0.56 (z=7.32), respectively.

About 17 per cent farmers got cacao seedlings from the government program. These farmers were expected to have higher yields than farmers buying seeds from other sources. However, model results reported in Table 2 show that the yield of cacao trees was not significantly higher for farmers who obtained cacao seedlings from the government program than for farmers who obtained their cacao seedlings from other sources. Most farmers (51 per cent) commented that good cacao seedlings were hard to get in their region. Furthermore, the prices of cacao seedlings were considered expensive by farmers and, therefore, they planted cheaper, low-quality seedlings (cited by 56 per cent of farmers). The price of a good seedling produced by PT Inang Sari (a certified cacao breeder located in West Sumatra) was Rupiah 3,500[4] at the time of the survey. To grow cacao trees on one hectare, farmers need to buy approximately 1000 seedlings, at a cost of Rupiah 3,500,000, while the price of a local cacao seedling at the time of the survey was Rupiah 2,000. This cost difference is the reason why farmers prefer to buy local seedlings.

Farmers did not consider infestations of pests and diseases in West Sumatra to have a significant effect on cacao production. It is a surprising result given that 41 per cent farmers reported that they faced this problem and 25 per cent of farmers claimed to have lost cacao output of more than 50 per cent. Further research is needed to examine this discrepancy between model and survey results.

Among the three variables presumed to affect cacao prices received by farmers, only distance was found to be significant with a standardized coefficient of −0.34 (z=−3.93). It means that the farther the location of farmers from the export point the lower the price they received. This figure implies a higher transportation cost for cacao beans located in more remote locations.

The low quality of cacao beans and bargaining position of farmers were hypothesized to have negative and positive relationships, respectively, with on-farm price in the original model. But these variables were found not to have significant relationships. This implies that farmers hold the view that the cacao price they receive is affected by factors that are not included in the model, most obviously by exogenous factors related to spatial price formation.

The issue identified in the workshop that low quality of cacao beans is a production problem in the cacao industry was confirmed by most respondents (61 per cent) in the survey. Model results reported in Table 2 show that, among the three possible causes, only *drying* (the number of drying days) (β=−0.23, z=−2.47) was thought by farmers to contribute significantly to the low quality of their cacao beans. The sign of the path coefficient from the *drying* to *lowq* (low quality of cacao beans) is negative, which is in line with expectations. The negative coefficient means that farmers expect a longer drying period to lead to a better quality of cacao beans.

The effect of the *condpods* (condition of pods harvested) on *lowq* does not have the expected sign. This result contradicts the theoretical perspective that when farmers harvest unripe pods it leads to a lower quality of bean. This issue needs further investigation.

The main reason for harvesting unripe pods proffered by 25 per cent of sampled farmers was squirrel attack. Results reported in Table 2 show a significant relationship between *squirrel* (squirrel attack) and *condpods* (β=−0.63, z=−11.84) with the expected negative sign on the path coefficient. It can be interpreted that the occurrence of squirrel attack discourages farmers from harvesting ripe pods. It means that attention should be paid to this issue; otherwise, it threatens the volume and quality of output of cacao beans.

An additional path suggested by modification indices from *pest and disease attack* to *condpods* results in a significant relationship between these variables (β=−0.15, z=−2.06). It indicates that pest and disease attack on their cacao trees worried farmers concerned with the spread of the infestation of pests and diseases to healthy pods that would cause greater losses. With pods subject to attacks by pests and diseases, farmers are tempted to harvest unripe pods as long as cacao beans coming from the unripe pods could be sold at the same price as ripe pods.

Building the model with an additional path from *farmbargain* to *condpods* improved the model fit. Farmers considered their ability to bargain on cacao price significantly affects the condition of pods they harvested (β=0.15, z=2.07). Those farmers who are able

[4] In early September 2013, 1,000 Indonesian Rupiah were approximately equivalent to £0.057, €0.067, and $US 0.088 (www.xe.com).

to bargain with buyers on cacao price tend to harvest riper pods. In this case, cacao beans from riper pods should be of better quality than those from unripe pods.

Fermentation practices are hypothesized to be positively correlated with the incentive of a price difference between proper fermentation and improper fermentation of cacao beans. Results reported in Table 2 prove that farmers identified a strong relationship between fermentation practices and the variable of no price difference ($\beta=-0.55$, $z=-9.36$). This estimate means that farmers will increase the period of fermentation if there is a price difference between appropriately and inappropriately fermented cacao beans. In other words, the proper fermentation technique would be adopted if there were a higher price received for appropriately fermented cacao beans.

Finally, results show that farmers located at a distance from the export point conducted fermentation for a longer period ($\beta=0.32$, $z=4.48$). This may relate to training conducted in remote locations where fermentation was the main piece of extension information obtained by farmers. Farmers expected that they could obtain a good price for their cacao beans if they fermented the properly. Unfortunately, this study reveals that better fermentation practices do not guarantee that farmers get a higher price.

Decomposition of effects of predictor variables on cacao income

Effects can be direct or indirect. Direct effect refers to the effect of one variable on another without involving intervening variables. An indirect effect is the effect of one variable on another that is transmitted through intervening variables. The sum of direct and indirect effects is defined as the total effect. Alwin and Hauser (1975, p. 39) noted that 'a total effect tells us how much change in a consequent variable is induced by a given shift in an antecedent variable, irrespective of the mechanisms by which the change may occur'. Indirect effects show how intervening variables influence the change in other variables, which in turn change the consequent variable.

The decomposition of the effect of predictor variables allows us to interpret the effects of each variable in the model. The standardized estimates of the effects of predictor variables in the model are presented in Table 3. Results suggest that support to increase the production of cacao trees and cacao market improvement are critical requirements to increase small farmers' income.

Among 17 factors in the model, seven factors are found to influence the gross income of cacao farmers. The indirect effects of predictor variables are transmitted through *yield* and *farmprice*. Of all the significant variables, yield has the strongest effect on cacao income (0.972). The second most important effect is cost of fertilizer (0.352), followed by farm price (0.187) and distance (0.139). While the total effects of cost of fertilizer and distance are constructed by indirect effects, the total effects of farm price and yield on farmers' gross income are due solely to a direct causal effect.

The effect of fertilizer use on farmers' gross income is mediated by yield. This total effect (0.352) can be computed by decomposing the indirect effects. To make the computation easy to follow, the direct effect of one variable on another needs to be shown. The direct effect of spending money on fertilizer on yield is 0.362 and the direct effect of yield on cacao income is 0.972. Based on these values the results indicate that, of the total effect of farmers spending money on fertilizer on farmers' gross income, 0.352 ($=0.362\times0.972$) is directly transmitted by yield.

The effect of distance on cacao income involves three pathways. Along the first pathway, the effect is transmitted through farm price ($-0.338\times0.189=-0.064$). The effect is mediated in the second pathway via the effect of cost of fertilizer on yield and its subsequent effect on farmers' gross income ($-0.216\times0.362\times0.972=-0.076$). Along the third pathway, the effect is transmitted via three subsequent variables: fermentation practices, low quality of cacao beans and farm price ($0.317\times0.087\times0.063\times0.189=0.0003$).

Even though the total effect of lack of capital on cacao income is small, it has a strong effect on farmers' spending on fertilizer. Availability of capital at the farm level would increase cacao income through the effect of cost of fertilizer on yield and its subsequent effect on cacao income ($-0.282\times0.362\times0.972=-0.099$).

The effect of lack of access to credit in the model is an extension of lack of capital's effect on cacao income ($0.618\times-0.099=-0.061$). In a similar way, the effect of lack of information about credit in the model is extended via the effect of lack of access to credit ($0.563\times-0.061=-0.034$).

5. Discussion and conclusions

We presented results of an application of structural equation modelling in a path analysis framework to study farmers' views on causal relationships in cacao production. The application aims to identify the main production constraints faced by cacao farmers in West Sumatra. Two production issues analysed in this study were low yield of cacao trees and low quality of cacao beans. The analysis was conducted to identify factors influencing these issues by assessing the cause-and-effect relationships and to assess how these variables had an impact on farmers' gross income.

The yield of cacao trees had a direct effect on farmers' gross income while the effect of the quality of cacao beans was hypothesized to be transmitted through prices received by farmers. Of the five variables (source of cacao seedlings, cost of pest and diseases management, pest and disease attack, frequency of pruning and cost of fertilizer) presumed to be correlated to the yield of cacao trees, only the cost of fertilizer has a statistically significant effect that is in line with the expected direction of causation. This finding is consistent with the finding by Amusan *et al.* (2005) that minimal fertilizer use contributed to a decrease in the profitability of cacao farming.

Economic limitations were shown to discourage farmers from applying fertilizer. Lack of capital was found to be a critical factor that farmers thought indirectly affects their fertilizing practices. Lack of access to credit was perceived by farmers as a cause of lack of capital. Farmers believed that lack of collateral

Table 3: The effects of predictor variables in the model of cacao production

Endogenous variable	Exogenous variable	Standardized direct effect	Standardized indirect effect	Standardized total effect	z-value
cincome	*lackcapital*	-	−0.099	−0.099*	−2.90
	costfertlz	-	0.352	0.352*	3.89
	condpods	-	0.002	0.002	1.87
	ferment	-	0.001	0.001	0.91
	lowq	-	0.012	0.012	0.67
	yield	0.972	-	0.972*	88.61
	farmprice	0.187	-	0.187*	16.97
	lxcredit	-	−0.061	−0.061*	−7.86
	squirrel	-	−0.001	−0.001	−0.63
	nopricedif	-	−0.001	−0.001	−0.54
	drying	-	−0.002	−0.002	−0.64
	sourceseed	-	0.136	0.136	1.51
	pdattack	-	−0.062	−0.062	−0.68
	farmbargain	-	0.001	0.001	0.04
	nocollat	-	−0.015	−0.015	−1.75
	noinfocrd	-	−0.034	−0.034*	−2.10
	distance	-	−0.139	−0.139*	−3.21
yield	*lackcapital*	-	−0.102	−0.102*	−2.90
	costfertlz	0.362	-	0.362*	3.89
	lxcredit	-	−0.063	−0.063*	−7.86
	sourceseed	0.140	-	0.140	1.51
	pdattack	−0.063	-	−0.063	−0.68
	nocollat	-	−0.016	−0.016	−1.75
	noinfocrd	-	−0.035	−0.035*	−2.10
	distance	-	−0.078	−0.078	−1.93
farmprice	*condpods*	-	0.011	0.011	1.87
	ferment	-	0.006	0.006	0.91
	lowq	0.063	-	0.063	0.67
	squirrel	-	−0.007	−0.007	−0.63
	nopricedif	-	−0.003	−0.003	−0.54
	drying	-	−0.014	−0.014	−0.65
	pdattack	-	−0.002	−0.002	−0.60
	farmbargain	0.002	0.002	0.004	0.04
	distance	−0.338	−0.002	−0.337*	−3.58

*significant at α=0.05 using a two-tail test.

and lack of information on credit prevented them from getting credit.

The quality of cacao beans, the ability of farmers to bargain on the price of cacao beans and remoteness of farmers' location from export point were presumed to affect farm-gate price. However, the first two variables were found not to be significantly correlated to farm-gate price. This finding indicates that famers consider farm-gate price to be influenced by other factors not covered in the analysis.

Distance affects the production and marketing sides in the model. On the production side, it negatively affects farmers' willingness to apply fertilizer. The further the location from the export point, the lower the level of spending on fertilizer by farmers. This situation most likely relates to the price of fertilizer which is more expensive in more remote locations, making it less profitable to apply, but it was not explored in this study. Further research is needed to investigate fertilizer distribution.

On the marketing side, distance influences the cacao price at the farm gate. Farmers located farther from the export point received a lower price than those in close proximity. It does not seem that road condition is the cause because road infrastructure in the research location is in good condition. The difference in price by distance is assumed to relate to the marketing margin; however, this issue is not covered in this study.

In terms of the quality problem identified in the PIPA workshop, the quality of cacao beans is only measured based on dryness. Even though fermentation and condition of pods harvested theoretically affect the quality, these factors were not identified by farmers as significant. This suggests that no grading system exists in cacao marketing at the farm level. Evidence elsewhere indicates that such a grading system can have a positive impact on cacao quality and prices. For example, Anang *et al.* (2011) argued that the correct growing, drying and fermentation methods adopted by farmers contributed about 80 per cent to determine the quality of cacao beans. Farmers in Ghana allowed cocoa pods to mature properly before harvesting to ensure high-quality beans, according to Anang *et al.* (2011), and sorted out the good and bad beans to maintain the quality of cacao beans before selling them.

As well as confirming a number of expected causal relationships, the results yielded some unexpected findings. They provide support for further government intervention where existing conventional wisdom is substantiated, and for further research where it is not to determine whether the reason for the odd result lies with an exaggerated view of a problem in cacao production, a misguided perception of a problem by cacao farmers or a problem in model specification.

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REFEREED ARTICLE

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Understanding intentional food contamination attitudes: applying Ajzen's Theory of Planned Behavior to a sample of fruit and vegetable industry workers

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ABSTRACT
As a way of understanding the potential antecedents of intentional acts of food contamination, a framework that employs tenets of Ajzen's (1985) Theory of Planned Behavior (TPB) was utilized to assess employees' attitudes about committing such acts. In a sample of 123 employees from various links along a fruit and vegetable industry supply chain between Mexico and the United States, we found industry commitment and moral norm to be antecedents to attitudes toward intentional food contamination. We also found that both perceived behavioural controls (i.e. security measures) and attitude toward intentional food contamination positively related to intention to contaminate food. The value of applying the TPB model to this context is discussed.

KEYWORDS: Food defence; food security; perceived behavioural control; behavioural intentions

1. Introduction

Large scale product recalls are an increasing concern for both international and US based food companies as well as government agencies. While the effect of a recall can be significant in the US market, the impact on export markets worldwide can be devastating (Manning, Baines, and Chadd, 2005). Unintentional biological or chemical contamination of our food supply is an issue that has garnered much attention in recent times (Manning *et al*, 2005). However, scholars agree that both unintentional and intentional contamination of food systems is a distinct possibility that needs to be evaluated and analyzed at every level of preparedness planning (Bruemmer, 2003). Even though our food supply is much safer at this time than it has ever been, the public might not necessarily view it as such (Hutter, 2004). Arguably, this may be partially due to acts of intentional contamination from individuals or disgruntled employees that are reported in the media. There are many different dysfunctional behaviours that can be considered as injurious in workplace settings (Griffin and Lopez, 2005). Voluntary employee behaviours that violate organizational norms, such as intentional food contamination, can threaten the well-being of any organization, its members, or an industry (Robinson and Bennet, 1995). Recent examples of tainted food (e.g. tomatoes, peppers) in the US food supply clearly demonstrate the severe psychological and financial impact that unintentional food contamination can have on consumers. As such, tied to the need to secure the integrity of any food supply chain are concerns about those individuals that have access to food along any food supply chain. Although large scale unintentional food contamination has occurred more frequently than intentional contamination in the past, the threat of intentional food contamination is real (Lyonga, Nganje, Sellnow, Kaitibie, and Vinette, 2006). Although there is some research on biological security and risk assessment of food supply systems that are vulnerable to deliberate food contamination (Elad 2005; Kennedy and Busta 2007; Manning *et al* 2005; Sobel, Khan and Swerdlow 2002), no research to date has examined the decision making process of individuals as it relates to intentional food contamination. Therefore, through use of a theoretical framework aimed at predicting behavioural intentions, this paper seeks to understand attitudes and intentions of individuals as they relate to smaller scale isolated intentional contamination events. By understanding how individual attitudes toward intentional food contamination may contribute to this phenomenon, perhaps prevention of such acts could be achieved.

Research on attitudes toward intentional contamination is not only timely, but also necessary for the protection of our global food supply chain. Moreover, no research has examined the attitudes and intentions of the individual or individuals that may be considering an

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act of intentional food contamination for produce that crosses borders. As a way of understanding the potential antecedents of such intentional acts of food contamination, a framework that employs tenets of Ajzen's (1985) Theory of Planned Behavior (TPB) will be utilized to assess employees' attitudes about committing such acts. The TPB has been utilized extensively in an effort to understand what factors motivate behaviour. The details of the TPB will be discussed later. Although other frameworks that focus on a more criminal aspect of intentional food contamination could be applied here, the attitude, subjective norms, and perceived behavioural control components of the theory provide a strong structure for our research.

Therefore, this research applies the framework of Ajzen's theory in order to better understand how an individual's attitudes, subjective norms and perceived behavioural control may impact their disposition to intentionally contaminate food within a produce supply chain. By doing so, we hope to add support to TPB literature by including a novel application that warrants attention. Moreover, the practical knowledge that can come from this research could be applied to preventing acts of intentional food contamination. This study is part of a larger study focused on assessing food defence for border transfer on the United States southern border. As such, we deemed it appropriate to test our model on this sample. Specifically, this study examines a sample of workers employed in a fruit and vegetable industry supply chain that handle produce traversing the Mexican border in to the southwest United States.

International Food Supply Chains

In recent years, food supply chains have experienced an increasing trend toward expanded global sourcing of food items (Manning, Baines, and Chadd, 2005). Improvements in modes of transportation along with trade have allowed for the importing of food from international markets into the U.S. food supply to be more available. Moreover, because changes in international markets have lead to an increase in the demand for agricultural products domestically, the proliferation of willing international suppliers has increased. As a result, global expansion has worked to extend the length and complexity of food supply chains and has elevated the possibility of intentional food contamination, including the fruit and vegetable industry.

In the United States, fruit and vegetables comprise a large group of food products that are imported on a regular basis throughout the year. About twenty percent of all fruits and almost twenty-five percent of all vegetables are transported in to the US annually. The farm value of these fresh fruit and vegetables reached $35 billion dollars in 2007 (NFAPP, Baseline Book, 2007), with this figure expected to exceed $40 billion by 2016. Additionally, as a result of these increasingly complex supply chains, responding to food emergencies is becoming more and more challenging. Consequently, the inability to respond quickly to food contamination emergencies, whether from an intentional or natural source, could have detrimental consequences to public health as well as trade practices in many countries (World Health Organization, 2002). In essence, understanding factors that contribute to the possibility of intentional food contamination could be very beneficial.

Although the United States has initiated several private and public efforts to mitigate the risk of a food emergency within the US food supply, imported foods are increasingly becoming vulnerable to intentional contamination. Examples of public sector investments in the United States include the Public Health Security and Preparedness Act of 2002; the Customs Trade Partnership against Terrorism (C-TPAT), the Container Security Initiative (CSI) along with several federal and state funded research initiatives (Dorgan, 2002; Koch, 2002). These efforts have increased in an attempt to prevent intentional food contamination by identifying the potentials risks involved in the movement of food products. By applying Ajzen's theory of planned behaviour to understanding attitudes toward intentional food contamination, we too seek to contribute practical knowledge. As such, understanding how and why individuals contemplate intentional food contamination in the first place could lead to a better realization of how to prevent occurrences of such acts.

Ajzen's Theory of Planned Behaviour

Ajzen's (1985, 1991) Theory of Planned Behaviour (TPB) is an extension of Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA). The TPB posits that *behavioural intentions* are the main determinants of behaviour. An individual's intentions are in turn determined by one's attitude toward the behaviour, subjective norms, and perceived behavioural control. In essence, people do things that they intend to do and do not do things that they do not intend to do. *Attitude* is the person's overall evaluation of what it would be like to perform a particular behaviour (e.g. 'It would be good/bad for me to do X'), while *subjective norm* is the person's perception of social pressure to perform the behaviour (e.g. 'Most people who are important to me think that I should do X'). *Perceived behavioural control* represents perceptions regarding the ease or difficulty of performing the target behaviour. Along with intention, perceived control is regarded as a co-determinant of behaviour, although the perceived control-behaviour relationship is dependent on the accuracy of people's perceptions of control (Ajzen, 1985).

From an empirical perspective, the TBP model has received a substantial amount of support, and has been successfully applied across a wide array of situations in an attempt to predict diverse human behaviour (Ajzen, 1991, 2002; Armitage and Conner, 2001; Conner and Armitage, 1998; Rivis and Sheeran, 2003). For example, the TBP has been applied to understanding computer abuse within organizations (Lee and Lee, 2002), binge drinking among young people (Norman, Bennett and Lewis, 1998), people's recycling behaviour (Tonglet, Phillips and Bates, 2004), the use of illicit substances (Orbell, Blair, Sherlock, and Conner, 2001), and software piracy in the workplace (Peace, Galleta and Thong, 2003). By applying this framework to understanding potential acts of intentional food contamination, we seek to contribute to a better understanding of the cognitive processes that potential perpetrators of such acts might go through. Doing so would not have practical implications, but this research would add to the rich literature that has garnered support for this robust theoretical framework.

TBP and Intentional Food Contamination

As noted earlier, Ajzen's Theory of Planned Behaviour (1985, 1991) has distinct components that are posited to impact a person's behaviour with one's intention being the immediate antecedent to that behaviour. In recent years, examples of outbreaks resulting from intentional food contamination illustrate how effectively food can be used to wreak havoc. Moreover, a wide range of people for a variety of reasons have committed these acts of intentional food contamination. Some examples of perpetrators include, cult members in 1984 injecting *Salmonella* into food in a salad bar in Oregon in an attempt to influence election outcomes, a disgruntled employee in 1996 contaminating pastries in a Texas hospital causing cases of Shigella dysenteria, a baker in 2002 contaminating the flour of a competitor with rat poison killing thirty-eight people, and a Michigan grocery store employee intentionally contaminating 200 pounds of meat in 2003 with insecticide causing over 100 people to become ill. These examples illustrate the diversity of the individual's willingness and ability to commit such acts of food contamination once they have intended to do so. Therefore, the need to better understand intentional food contamination from the perspective of the Theory of Planned Behaviour seems warranted. Arguably, the application of the TPB can provide valuable insight into the thought processes behind intentional food contamination behaviour.

2. Proposed Model and Hypothesis Development

To our knowledge, this is the first application of the TPB to examine intentional food contamination so it must be considered exploratory in nature. As such, the choice of non-directional hypotheses seems justified. This application of Ajzen's TPB to intentional food contamination is visually depicted in Figure 1. This figure is similar to one previously used by Bailey (2006).

As with other applications of the TPB framework, our model suggests that intention to engage in food contamination can be impacted by an individual's attitude toward that behaviour, the subjective norms associated with that behaviour, and the perceived ease or difficulty of engaging in the act itself. As previous research has shown, the inclusion of additional antecedent variables can add to a better understanding of one's intention to behave in a particular way (Ajzen, 2002; Bailey, 2006; Landridge *et al*, 2007). As such, we have chosen two additional variables to include in our model and the rationale for their inclusion will be explained below.

Generally speaking, favourable attitudes and supportive group norms can influence a strong intention to perform followed by actual performance of a behaviour (Stone, Jawahar and Kisamore, 2008). However, perceived behavioural control can impact both the level of one's intentions as well as the intentions to behaviour relationship. For example, a disgruntled employee may have a favourable attitude toward contaminating food that is shared by his co-workers, but the level of security measures that monitor the food distribution may make intentional contamination extremely unlikely.

Individual Factors

As previously mentioned, TPB allows for additional variables to be included in the model and researchers have done so with much support (Ajzen, 2002; Bailey, 2006; Landridge *et al*, 2007). Accordingly industry commitment and moral norm have been included as factors that contribute to one's attitude toward intentional food contamination. A brief discussion on the inclusion of these individual factors in our model follows.

Industry commitment

The industry commitment scale utilized in this study was derived from the organizational commitment scale that gauges an individual's degree of loyalty to his/her particular employer. Because the food supply chain examined in this study includes entities such as field workers, growers, truckers, and distributors that contribute collectively to the fruit and vegetable industry, measuring an overall degree of commitment to the fruit and vegetable industry was appropriate. Each link along

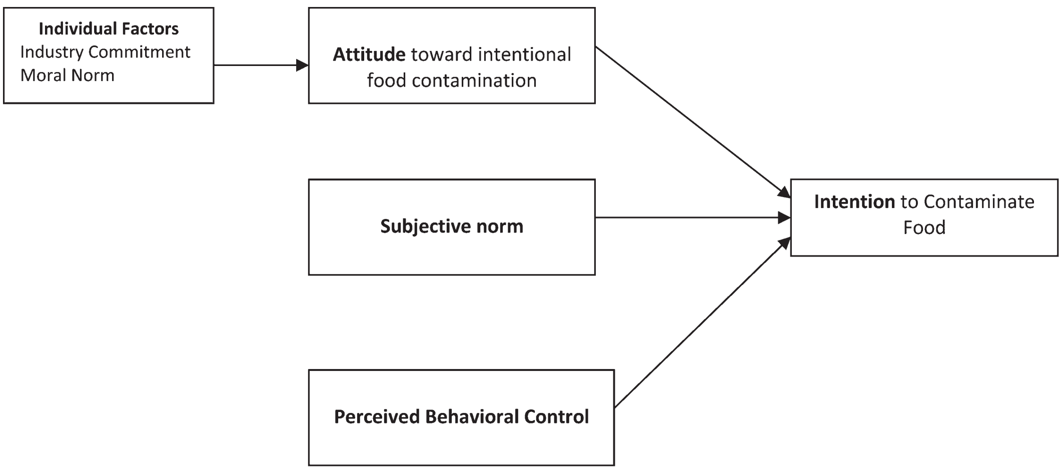

Figure 1: Theory of Planned Behavior applied to intentional food contamination (Bailey, 2006)

the supply chain depends on the other in order to get the product to the client. If the industry as a whole is to be successful, each separate entity must be committed to do its part for the industry. As such, each entity is aware that they are part of a larger entity that is the fruit and vegetable industry. Organizational commitment refers to the psychological attachment of workers to their workplaces (Allen and Meyer, 1990; O'Reilly and Chatman, 1986) that makes it less likely that the employee will voluntarily leave or harm the organization (Allen and Meyer, 1996). As applied to this model, it is argued that one's level of commitment to the fruit and vegetable industry will impact one's attitude toward intentional food contamination. To our knowledge, this is the first adaptation of the organizational commitment measure to represent commitment to an industry. If one has a high level of commitment to the industry, one's attitude toward intentional food contamination would be negative. In other words, someone committed to the industry would not think of intentional food contamination as a good thing. Accordingly, the following hypothesis is suggested:

H1: Industry commitment is related to attitude toward intentional food contamination.

Moral norm

Moral norm refers to a person's sense of obligation to perform ethical behaviours as opposed to unethical ones (Langridge, Sheeran and Connoly, 2007). Scholars suggest that one's moral norm is independent of the influence and expectations of even significant others (Manstead, 2000). Previous scholars employing a TBP perspective have included a moral norm measure when examining shoplifting attitudes (Tonglet, 2002) information technology (IT) ethical behaviour (Leonard, Cronan, and Kreinie, 2004), and have examined the link between an individual's moral code and their subsequent behaviour (McMillan and Conner, 2003). We chose to include this variable in our model because this issue of intentional food contamination includes a component of what people may consider 'right' or 'wrong'. As applied here, it is posited that if an individual has a high moral norm, their attitude toward intentional contamination would be negative. In other words, someone with a high moral norm would not think of intentional food contamination as a good or 'right' thing to do. As such, the following hypothesis is suggested:

H2: Moral norm is related to attitude toward intentional food contamination.

TPB Factors

Attitude toward intentional food contamination

As previously mentioned, attitude is a person's overall evaluation of what it would be like to perform a particular behaviour (e.g. 'It would be good/bad for me to do X'). In other words, attitude represents the degree to which a behaviour or action is positively or negatively valued. In general, if a person has an unfavourable attitude toward a particular behaviour, the less likely it is that the person will engage in that behaviour. Accordingly, we expect that a person with a negative attitude toward intentional food contamination will be less likely to intend to contaminate food. It therefore follows that:

H3: Attitude toward intentional food contamination is related to intention to engage in food contamination.

Subjective norms

Subjective norms represent perceived social pressure to engage or not to engage in a particular behaviour (Ajzen, 1991). What this suggests is that people consider the perceptions of significant others when deciding whether to engage or not to engage in a certain behaviour. Significant others may or may not include family members, friends, supervisors, or co-workers. Previous studies have garnered support for the impact of subjective norms on drivers' intentions to commit specific driving violations (Parker, Manstead, Stradling, Reason, and Baxter, 1992), drivers' intentions to comply with speed limits (Elliott, Armitage, and Baughan, 2003), and consumer decision making (Ajzen and Driver, 1992). We expect that the more unsupportive an individual's subjective norms are of intentional food contamination, the less likely will be an individual's intention to contaminate food.

H4: Subjective norms are related to intention to engage in food contamination.

Perceived behavioural control

Perceived behavioural control is the person's perception of the extent to which performing a behaviour is under his/her control and typically is measured by ratings of the ease versus difficulty of performing the behaviour (e.g. 'For me to do X would be easy/difficult'). Basically, perceived behavioural control should be associated with intentions because a person is less likely to perform a behaviour that is perceived to be outside of their control. Previous research has linked perceived behavioural control to intentions to engage in shoplifting (Tonglet, 2002), exercise intentions (Rhodes and Courneya, 2004), online transaction intentions (Pavlou and Chai, 2002) and breakfast choice intentions in adolescents (Gummeson, Jonsson, and Conner, 1997). Regarding intentional food contamination, perceived behavioural control may be impacted by the level of security measures in place along the supply chain. For example, security cameras may be used in packing areas at production locations, storage areas, and warehouses. Moreover, shipment tracking tools such as 'smart box' technology can be utilized while produce is in transport mode on trucks. Such tracking systems cannot only provide security benefits, which are the foremost goal in food contamination prevention, but, they can also provide importers and exporters significant cost savings from decreased shrinkage or spoilage. The presence of such security and tracking measures are therefore put in place to dissuade individuals from participating in dysfunctional or destructive behaviour. In the current study, it is expected that a lack of perceived behavioural control will dissuade individuals from intending to engage in food contamination. In other words, we expect that if individuals perceive no control over being undetected while contaminating food intentionally, they will be less likely to intend to contaminate food. Accordingly, it follows that:

H5: Perceived behavioural control is related to intention to engage in food contamination.

3. Methods

Sample and Procedure

A Food Defence Plan Assessment survey developed by the U.S. Department of Homeland Security (DHS) and the Department of Agriculture-Food Safety and Inspection Service (USDA-FSIS) for meat and poultry was customized to include unique features of fruit and vegetable growers, with particular emphasis on cross border food shipment security. An iterative review process was utilized to ensure content validity. A preliminary version of the survey was pilot tested with numerous academic experts and industry participants. Based on feedback gathered from this process, the survey was modified and the original English version was translated into Spanish and back-translated into English. Review by native Spanish speaking research assistants found no evidence of any significant difference between the original and the translated and back-translated versions. Participants were offered the choice of a Spanish or English questionnaire.

Because the produce industry involves many entities along a supply chain, a paper and pencil questionnaire was filled out by, and collected from, each full-time employee representing various links along this particular supply chain. All respondents were employed at the time of the survey and all data collection occurred on-site, face-to-face, and during work hours. Because of the nature of the survey it was completely anonymous and other than the specific link along the supply chain (e.g., trucker), no individual identifiers were collected. The diverse sample includes, farm workers, truckers, wholesalers and distributors of fruits and vegetables coming from Mexico. As a result, it seems reasonable to suggest that this study gauged a viable representation of the fruit and vegetable industry as it pertains to produce traversing the Mexican border in to the southwest United States. One hundred and twenty three completed questionnaires were collected (n=123) and used in our analyses. The demographic breakdown of the participants was: 82% male; 54% Hispanic, 28% Caucasian, 16% other, 2% African-American; 45% had high school, and 30% had some college; and a mean age of 39.32 (SD=10.49).

Measures

Survey participants responded to several measures including: industry commitment, moral norm, attitudes toward intentional food contamination, subjective norms toward intentional food contamination, perceived behavioural control over intentional food contamination, and intention to contaminate food. With the exception of industry commitment, all measures have been previously validated in prior research utilizing a Theory of Planned Behaviour framework.

Industry commitment

Industry commitment was measured with five items adapted from Meyer, Allen, and Smith's (1993) organizational commitment affective component measure. Employees rating high in affective commitment stay with organizations because they *want* to. An example item of this measure is, *'I would be very happy to spend the rest of my career working in the fruit and vegetable industry'*. Subjects were asked how much they agree with statements on a 5-point Likert scale with 1='strongly disagree' to 5='strongly agree'. Cronbach's alpha is (α=.93).

Moral norm

Moral norm was measured with 3 items adopted from Tonglet (2002). An example item of this measure is, *'contaminating food at work on purpose is against my principles'*. Subjects were asked how much they agree with statements on a 5-point Likert scale with 1='strongly disagree' to 5='strongly agree'. Cronbach's alpha is (α=.89).

Attitude

Attitude toward intentional food contamination was assessed with three pairs of semantic differentials (Elliott, *et al.* 2003). For example, the statement *'To me, contaminating food on purpose is:…….'* was completed with the semantic differential choices of *unattractive/attractive, foolish/wise, dishonest/honest.* Respondents were asked to circle the word that they felt best completed each statement. Scores of 1 were given to negative attitudes while a score of 2 was given to positive attitudes. In other words, a lower score reflects a negative attitude toward intentional food contamination. The mean of the three items was calculated to produce a composite scale. Cronbach's alpha is (α=.83).

Subjective norm

Subjective norms toward intentional food contamination were measured with four items adapted from Elliott, *et al.* (2003). An example item of this measure is, *'most of the people who are important to me would look down on me if I were to contaminate food at work on purpose'*. Subjects were asked how much they agree with statements on a 5-point Likert scale with 1='strongly disagree' to 5='strongly agree'. Cronbach's alpha is (α=.90).

Perceived behavioural control

Perceived behavioural control over intentional food contamination was measured with three items adapted from Elliott *et al.*, (2003). An example item of this measure is, *'the control systems in place at work makes it easy for other employees and me to contaminate food on purpose'*. Subjects were asked how much they agree with statements on a 5-point Likert scale with 1='strongly disagree' to 5='strongly agree'. Cronbach's alpha is (α=.75).

Intention to contaminate food

Intention to contaminate food was measured with three items. An example item of this measure is, *'Even if I had the opportunity, it is highly unlikely that I would*

Table 1: Descriptive statistics, reliability coefficients, and correlations

Variables	Mean	SD	1	2	3	4	5
1. Industry Commitment	2.84	1.43	(0.93)				
2. Moral Norm	3.71	1.66	0.66**	(0.89)			
3. Attitude	1.16	0.33	0.34**	0.31**	(.83)		
4. Perceived Behavioral Control	2.24	1.26	0.46**	0.62**	0.23**	(0.75)	
5. Intentions	3.99	1.76	0.64**	0.87**	0.27**	0.58**	(0.94)

Note: Coefficient alphas estimating reliabilities are in parentheses along the diagonal
*$p<0.05$
**$p<0.01$

contaminate food at work on purpose'. Subjects were asked how much they agree with statements on a 5-point Likert scale with 1='strongly disagree' to 5='strongly agree'. Cronbach's alpha is (α=.94).

4. Results

The descriptive statistics and correlations for all variables appear in Table 1. The hypotheses were tested using regression analysis. Two-tailed tests were used in interpreting statistical significance. All scales were subjected to content validation and were analyzed for reliability.

Exploratory Factor Analyses (EFA) using principle components analysis and varimax rotation were conducted on the eight individual factor items. The EFA showed the expected two factor solution loading on each factor for both industry commitment and moral norm measures equal to or larger than 0.40 with an eigenvalue greater than 1. Table 2 shows the final result of a two-factor solution retaining 5 items for industry commitment and 3 items for moral norm. Reliability analyses yielded acceptable Cronbach alphas.

Exploratory Factor Analyses (EFA) using principle components analysis and varimax rotation were conducted on the 13 items representing Ajzen's Theory of Planned Behaviour model. After several iterations, the subjective norm items did not converge on a unique factor. Previous research has suggested that the normative component of the TBP model may be the weakest component due to weak measurement (Armitage and Conner, 2001). Because prior meta-analyses have found subjective norm to be the weakest predictor of intentions (Godin and Koch, 1996), researchers have deliberately removed subjective norms from analysis (Armitage and Conner, 2001). As a consequence of the less than optimum factor analysis results for this variables in the overall model, subjective norms was removed from the model and hypothesis 4 was not tested. A subsequent EFA conducted on the remaining items showed the expected three-factor solution loading on each factor for attitudes, perceived behavioural control, and intention measures equal to or larger than 0.40 with an eigenvalue greater than 1. Table 3 shows the final result of a three-factor solution retaining 9 items; 3 items for attitude, 3 items for perceived behavioural control and 3 items for intentions. Again, reliability analyses yielded acceptable Cronbach alphas.

Hypothesis 1

To examine the relationship of industry commitment and attitude toward intentional contamination, a univariate regression analysis was conducted. It was hypothesized that industry commitment would be related to a negative attitude toward intentional contamination. As shown in Table 4, when attitude toward intentional food contamination was regressed on industry commitment, the regression equation was statistically significant as follows: (F=15.93, p<.01). There was also a significant positive beta weight (b=0.34, $p<0.01$). Thus, Hypotheses 1 was supported.

Hypothesis 2

To examine the relationship of moral norm and attitude toward intentional contamination, a univariate regression analysis was conducted. It was hypothesized that moral norm would be related to a negative attitude toward intentional food contamination. As shown in Table 4, when attitude toward intentional contamination was regressed on moral norm, the regression equation was statistically significant as follows: (F=12.76, p<.01).

Table 2: Exploratory factor analysis results: industry commitment and moral norm

Industry Commitment	Factor1	Factor2
I really feel as if the fruit and vegetable industry's problems are my own.	**0.88**	0.19
I feel like I am part of the fruit and vegetable industry.	**0.83**	0.35
I feel "emotionally attached" to the fruit and vegetable industry.	**0.81**	0.31
The fruit and vegetable industry has a great deal of personal meaning for me.	**0.80**	0.31
I would be very happy to spend the rest of my career working in the fruit and vegetable industry.	**0.79**	0.38
Moral Norm		
Contaminating food at work on purpose is morally wrong.	0.34	**0.86**
I would feel guilty if I were caught contaminating food at work on purpose	0.23	**0.91**
Contaminating food at work on purpose is against my principles.	0.36	**0.79**
Eigenvalue	5.04	0.77
Percent of Explained Variance	87%	13%

n=123; Factor 1=Industry Commitment, Factor 2=Moral Norm

Table 3: Exploratory Factor Analysis: Intentions, Attitude, Perceived Behavioural Control

Intention to Contaminate Food	Factor1	Factor2	Factor3
If I saw someone contaminating food at work on purpose, I would not report them because it is none of my business	**0.90**	0.15	0.33
I have no intentions of ever contaminating food at work on purpose	**0.81**	0.06	0.23
Even if I had the opportunity, it is highly unlikely that I would contaminate food at work on purpose.	**0.92**	0.15	0.31
Attitude Toward Intentional Food Contamination			
To me, contaminating food on purpose is: Unattractive /Attractive	0.02	**0.85**	0.08
To me, contaminating food on purpose is: Foolish/Wise	0.12	**0.85**	0.04
To me, contaminating food on purpose is: Dishonest/Honest	0.12	**0.70**	0.20
Perceived Behavioral Control			
The control systems in place at work makes it easy for other employees and me to contaminate food on purpose.	0.15	0.13	**0.64**
There are many opportunities at work for other employees and me to contaminate food on purpose.	0.28	0.21	**0.63**
It is unlikely that I would get caught if I were to contaminate food at work on purpose	0.38	−0.04	**0.60**
Eigenvalue	2.60	2.04	1.47
Percent of Explained Variance	42%	33%	24%

n=123; Factor 1=Intentions, Factor 2=Attitudes, Factor 3=perceived behavioral control

There was also a significant positive beta weight (b=0.31, p<0.01). Thus, Hypotheses 2 was supported.

Hypothesis 3

To examine the relationship of attitude toward intentional contamination and intention to contaminate food, a univariate regression analysis was conducted. It was hypothesized that attitude toward intentional contamination would be related to intention to contaminate food. As shown in Table 4, when intention to contaminate food was regressed on attitude toward intentional contamination, the regression equation was statistically significant as follows: (F=9.62, p<.01). There was also a significant positive beta weight (b=0.27, p<0.01). Thus, Hypotheses 3 was supported.

Hypothesis 5

To examine the relationship of perceived behavioural control and intention to contaminate food, a univariate regression analysis was conducted. It was hypothesized that perceived behavioural control would be related to intention to contaminate food. As shown in Table 4, when intention to contaminate food was regressed on perceived behavioural control, the regression equation was statistically significant as follows: (F=61.58, p<.01). There was also a significant positive beta weight (b=0.58, p<0.01). Thus, Hypotheses 5 was supported.

5. Discussion

Researchers suggest that a key vulnerability that we as individuals have is our fear for our health (Homer-Dixon, 2002). Possibly, one way to strike at the health of any industrialized nation would be to attack its food-supply system (Homer-Dixon, 2002). Without a doubt, intentionally contaminating a food source would not only prove to be physically detrimental to the public by potentially causing illnesses and perhaps even deaths, but it could also foster wide-spread panic. Moreover, as we have seen from recent occurrences of unintentional food contamination, the negative financial and economic impact intentional food contamination could have would be devastating. The present study provides some evidence supporting the application of the Theory of Planned Behaviour in understanding intentional food contamination. An intentional attempt to contaminate food along any of the various nodes of the food supply chain (i.e., farm, packing, check points) could be detrimental to the economies of several local communities across the US border, whose livelihood depends on operating within a secure food delivery system. Accordingly, information gathered from research in this area is vital for the implementation of a viable food defence plan for organizations.

Strengths, Limitations, and Future Research

One strength of our study is that it offers initial support for the viability of our industry commitment measure.

Table 4: Regression Analysis Results

	Intentions	Attitude	R^2	Adjusted R^2	ANOVA F
Perceived Behavioral Control	0.58** (0.05)		0.34	0.33	61.58**
Attitude	0.27** (0.28)		0.07	0.06	9.62**
Industry Commitment		0.34** (0.22)	0.11	0.10	15.93**
Moral Norm		0.31** (0.26)	0.09	0.08	12.76**

Note: Regression weights are standardized beta weights (β)standard errors (SE β) appear in parenthesis; n=123
*p<0.05
**p<0.01

Where appropriate, measuring the level of industry commitment individuals have and understanding the impact that it may have on employee attitudes and subsequent behaviours could be valuable. Another strength of this research is a solid theoretical framework. As pervious research has found, the application of the Theory of Planned Behaviour can and should continue to be applied in a variety of settings and contexts in order to predict behaviour.

One limitation of this study was our inability to include subjective norms in our analyses. As explained earlier, this is not uncommon and previous research has excluded the subjective norm component from their investigations. Although we would have preferred including the entire model, perhaps our measure was unable to capture the essence of the subjective norm concept, and as a result our participants could not distinguish it from other measures on the survey.

Further limitations of the present study are also apparent and require attention. The relatively small sample size in this study and the fact that all the data collected came entirely from self-reports both represent major limitations. The cross-sectional nature of the data collection represents another limitation. Although collecting data from independent samples could alleviate this limitation, perhaps a longitudinal design with a series of data collections could be employed in subsequent research.

Considering the strengths and limitations of this research, our findings hold promise for further inquiry. Future research could focus on testing this model in a variety of industry contexts. For example, given the recent problems in the financial sector of the US economy, it would be interesting to see how commitment to that industry would impact attitudes, social norms, perceived behavioural control and intentions to behave ethically. Future research should also continue the validation process in a larger field sample or with a set of field samples. Further work on the subjective norm variable will also need to be conducted in order to test the complete theoretical model in the future. For instance, future research may examine perceptions of perceived behavioural control in order to determine what area along the food supply chain employees may indicate the relative ease of access in an effort to commit such a damaging act. Future research should also further examine the moral norm construct in other workplace settings. For example, instances of organizational corruption or unethical corporate behaviour might be viewed from the moral norm lens as it relates to the TPB framework. Lastly, future research should employ a multi-source design to substantiate claims made by participants. By continuing to develop this model and applying it to other industries, its inclusion could provide an avenue for additional theorizing regarding its impact on other workplace attitudes. Until then, our findings must be viewed as incomplete.

6. Conclusion

Although we were unable to test the model of Ajzen's Theory that includes a measure for subjective norms, our findings involving the remaining variables provide valuable information. Consistent with prior research, we found that the relationship between attitudes and intentions was indeed a positive one. In other words, in this sample, we found that a negative attitude toward intentional food contamination contributed to a lowered intention to contaminate food. As previously mentioned, if organizations can increase the level of commitment that employees share about the industry as a whole, they may be able to positively impact attitudes in such a way that intentional food contamination would be unlikely. Another interesting finding from this sample was that the strongest relationship in our model seems to be between perceived behavioural control and intentions to contaminate food. This too is consistent with prior research that has found this relationship to be strong. Our results suggest that individuals in fact see the security measures that are in place as a deterrent to such negative behaviours. In other words, the possibility of being discovered committing such acts by security measures in place goes a long way to influencing intentions. This is good news for organizations in the fruit and vegetable industry that invest a lot of money on surveillance equipment in warehouses and tracking devices on modes of transportation. Although there is a considerable upfront cost for such security measures, the cost of not doing so could be much higher. Because preventing acts of intentional food contamination is a high priority for all participants along the food supply chain, an understanding of what steps to take in order to dissuade individuals or groups from considering such acts is invaluable.

One contribution of this research is our inclusion of industry commitment as an antecedent of attitude. Consistent with the perspective that attitudes toward intentional food contamination can be influenced by individual factors such as industry commitment and moral norms, it was hypothesized that both individual factors would be related to negative attitudes toward intentional food contamination. Our results suggest that the more an individual felt committed to the fruit and vegetable industry, the more likely they would be to perceive acts of intentional contamination as a bad thing. Managers could benefit from this information and take steps to increase all employees' level of commitment as a way to prevent attitudes that are tolerant of intentional food contamination. Additionally, we found that the more a person felt a sense of obligation to perform ethical behaviours as opposed to unethical ones (moral norm), the more likely they would be to perceive acts of intentional contamination as corrupt. These findings are consistent with previous research that has suggested that moral norms are closely linked to attitudes and may in some instances are able to be an antecedent to behaviours (Conner and Armitage, 1998).

Suppliers of produce are still recovering from the economic losses they suffered as a result of food contamination occurrences. The high level of trust that consumers have in the US food supply system is something that cannot be taken for granted. Although unintentional food contamination in the system can reduce consumer's levels of trust, an act of intentional food contamination can potentially cause widespread panic that would be even more difficult to overcome. Assessing the combined health, economic and psychological impacts of such an attack within the food industry would be challenging to quantify. Reactions to this emerging source of food safety risks are often variable with some individuals developing symptoms of depression, post-traumatic stress disorder, and high levels of general anxiety or stress. As such, the psychological impact that such events can have on individuals, communities, or nations for that matter must not be overlooked. Accordingly, agencies and researchers should continue to investigate ways to prevent such acts. Because this study is the first to examine intentional food contamination from the perspective the Theory of Planned Behaviour and an international origin, the results must therefore be viewed as exploratory. However, the value of continued research in this area seems reasonably high.

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Public support for agriculture: perceptions of farming and environment among the British in 2012

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ABSTRACT

Farming and the countryside are viewed by the British public as important, to a much greater degree than suggested by their economic significance. This may indicate deep insight about the importance of food supply and ecosystems, which could in turn manifest itself through the Common Agricultural Policy, and legitimise the CAP.

KEYWORDS: Common Agricultural Policy; Environment; Farm subsidies; Public opinion; Britain

1. Introduction

The Common Agricultural Policy (CAP) represents the largest single policy expenditure of the European Union, accounting for 40% of the EU budget (European Commission, 2012). This has the objectives of maintaining food supply, promoting environmental quality and supporting farm incomes.

The rationale and justification for the CAP are matters of contention. A major consequence of the CAP through the 1980s and 1990s was the generation of commodity surpluses that had then to be taken off the market at considerable expense. However, more recent turbulence in world commodity markets is promoting some rethinking as to the importance of food security and domestic production.

With a growing world population, improving diets and finite land, food production is likely to become a more serious concern as time passes. Agriculture has both positive and negative impacts on the environment. Intensification and specialisation of farming systems had adverse impacts on the environment, especially since the 1970s (Pye-Smith & Hall, 1987) and arguably these continue now, as reflected in declining indices of farmland birds (Donald *et al.*, 2001) and bees (Goulson *et al.*, 2008). But at the same time, it is argued that in other circumstances the CAP maintains agricultural land uses against abandonment and so protects cultural landscapes (Renwick *et al.*, 2011). There is demand for protection of the rural environment (for example: Greenpeace.org; FoE.org; or CPRE).

Many environmental attributes have the property of 'public goods' (Samuelson, 1954), so it is argued that farmers should be paid to protect the environment, both because providing environmental goods has costs to farmers, and because they cannot charge for the environmental benefits enjoyed by the public (Hart *et al.*, 2011). This philosophy can be summarised in the phrase 'Public Goods for Public Money'. While the European Commission argues that farm household incomes lag behind those in other sectors (according to the European Commission (2012), the EU average of farmer income is 40% of average wages in total economy per full-time equivalent), in the UK farm incomes are often relatively high (Defra, 2013). So, according to the EU Commission [the role of agriculture] "is not only to produce food, but also to guarantee the survival of the countryside as a place to live, work and visit".

In the context of the severe pressures on public finances within the European Union and the CAPs mid-term review in 2017, political support for the maintenance of the CAP will be critical. Hence perceptions of farming, among the general public, are important, both to legitimise current state support, and to motivate beneficial changes. Thus, to gauge broad support in Britain for farming and the environment, a survey of the British public was carried out by YouGov in cooperation with the author. Results are contrasted with Eurobarometer surveys in 1982 and 1987, which examined ecology and the CAP.

2. Data

The survey was undertaken of 1,736 adults from an internet omnibus panel over 29–30 July 2012, and weighted to be representative of the UK. The survey was conducted by YouGov.

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Table 1: Perceptions of UK farming, among the British general public (July-2012)

		Voting intention			2010 Vote			Know about farming		Gender	
	Total	Con	Lab	Lib Dem	Con	Lab	Lib Dem	Great deal/ fair bit	Other	Male	Fem.
Weighted Sample	1736	443	586	119	548	459	378	453	1283	844	892
Unweighted Sample	1736	426	562	108	531	444	394			795	941
Question	%	%	%	%	%	%	%	%	%	%	%
Generally speaking, how much would you say know about farming in the UK?: TOTAL NOT VERY MUCH / NOTHING AT ALL	μ=72	70	75	** 62	69	** 77	71			*** 67	** 75
Farming is important for the economy in the local area where I live: TOTAL AGREE	μ=57	60	** 52	* 65	* 61	* 53	57	*** 73	*** 51	56	57
Farming is important for the UK economy as a whole: TOTAL AGREE	μ=85	***90	83	87	*** 89	85	87	*** 92	** 83	85	86
The share of the UK economy based on farming will get significantly smaller over the next 10 years: TOTAL AGREE	μ=62	62	62	62	65	61	59	** 67	** 59	60	62
Farming plays an important role in protecting the environment in the UK: TOTAL AGREE	μ=74	* 78	73	* 81	** 78	** 69	73	*** 85	*** 70	73	74
TOTAL DISAGREE	μ=4	4	5	5	** 2	*** 7	** 6	6	4	*** 6	4
How important to you, is it to live near countryside or other green spaces?: TOTAL IMPORTANT	μ=82	**86	* 79	86	** 86	* 79	85	*** 93	*** 79	80	** 85
TOTAL NOT IMPORTANT	μ=13	11	** 16	13	11	** 17	12	*** 6	*** 16	*** 16	*** 10
How often, if at all, do you visit the countryside or other green spaces? (e.g. public gardens, parks, forests, hills, nature reserves): Visits More than Once per month	μ=65	***72	*** 59	* 73	*** 72	*** 59	68	*** 83	*** 59	* 62	* 68

***p<0.01
**p<0.05
*p<0.1

Table 1 extended

Age				Social grade		Region				
18–24	25–39	40–59	60+	ABC1	C2DE	London	Rest of South	Midlands / Wales	North	Scot-land
210	443	594	490	990	746	222	564	372	427	151
115	503	640	478	1162	574	320	562	324	383	147
%	%	%	%	%	%	%	%	%	%	%
68	71	** 76	** 67	71	71	74	70	** 67	* 76	71
*** 47	*** 49	60	*** 65	55	58	*** 30	*** 66	** 63	* 53	56
*** 71	*** 80	** 88	*** 94	85	86	** 80	** 88	85	84	* 90
** 55	*** 56	62	** 67	*** 58	** 66	60	61	64	60	62
*** 65	*** 68	74	*** 84	74	73	70	75	74	75	70
4	** 6	5	4	5	3	5	4	4	** 6	4
*** 65	*** 77	*** 87	*** 89	83	82	*** 73	*** 88	85	80	78
*** 21	*** 18	** 10	** 10	14	12	*** 22	*** 9	* 10	14	** 20
*** 49	65	65	*** 72	67	63	*** 50	*** 75	** 70	*** 56	67

Table 2: Perceived threat to green spaces in the UK (July-2012)

Now thinking more generally about green spaces in the UK...Which, if any, of the following do you think are serious threats to the UK countryside? (Please select a maximum of two)	Total%
New houses being built	**42**
The dumping of rubbish	**38**
Damage to special areas or 'reserves' in the countryside, such as woodlands, marshes, wetlands and places where rare animals or insects live	**24**
New roads being built	**22**
Leaving land uncared for as 'wasteland'	**17**
Other types of new building (e.g. factories, offices, warehouses and shopping centres)	**14**
New or bigger airports being built	**12**
Farming	**4**
The countryside is not under threat	**2**
Other	**2**
Don't know	**7**

3. Results and discussion

A clear majority of respondents regarded farming as important for the economy - in the local area in which they live, and to the economy as a whole. We might contrast this with the contribution that agriculture makes nationally to Gross Value Added, at about 0.75% in 2007. Clearly, people may well see food production as having an importance beyond that financial measure.

Farming is thought to be important in protecting the environment in the UK by 74% of adults in Britain, and 85% think that it is important for the UK economy (Table 1.). More specifically, conservative voters were marginally more positive about farming's contribution. However, there is a clear relationship with age. People under 40, particularly the 18–24 age group, were rather less positive about farming, the farm environment, living near green spaces, or visiting the countryside. Social grades differed little, with only the perceived likelihood of diminution of the farm economy being somewhat smaller in ABC1 ('upper/professional/managerial' class). Only 4% disagree that farming is important for protecting the environment (Table 1.).

Those who state that they know 'a great deal' or 'a fair amount' about farming were more positive about across all measures. And females were more positive than males (Table 1.).

A majority of Londoners thought that farming is important for the economy (80%), and for the environment (70%) - but the proportions with these views were lower than in the other parts the country. This is as might be expected, given that London is so urban and that the countryside so remote from it. But it is perhaps surprising that only 22% of Londoners (the greatest proportion of any grouping) think that it is not important to live near the countryside or green spaces. Thus as 73% there think it is important to live near countryside or green spaces, this would seem to indicate very great significance to the limited green spaces that are available in London.

It may however be of concern that only 65% of 18–24 year olds think that being near countryside or green space is important - the fewest of any group. The relative lack of importance for the rural environment among the young could be an effect of age, or it may be the effect of younger generations adopting different lifestyles from older people.

Young people in the 1980s were somewhat inconsistent in the extent to which they expressed 'pro-environmental' sentiments. So perhaps the younger cohorts just reflect the issues of the day to a greater

Table 3: The Common agricultural policy as viewed by the EC and GB publics in 1987.[1]

	Age group					
	15–24	25–39	40–54	55 OR>	Total	n
The CAP can be supported, if it takes into account environment/nature	%	%	%	%	%	
GBR						
AGREE	85	82	89	88	86	603
DISAGREE	15	18	11	12	14	100
EC						
AGREE	88	89	91	92	90	7,780
DISAGREE	12	11	9	8	10	885
We should cut back on farm chemicals, even if produce is expensive						
GBR						
Total AGREE	73	91	94	93	89	624
Total DISAGREE	27	9	7	7	11	79
EC						
Total AGREE	85	90	90	89	89	7,672
Total DISAGREE	15	10	10	11	11	993

[1]Source: EuroBarometer 27, GESIS 1712, Mar-May 1987

Table 4: Ecological issues as viewed by the EC public in October 1982.[1]

	Age group							
	15–24	25–34	35–44	45–54	55–64	65 AND OVER	Total	n
Do you have reasons to complain about 'Loss of farmland'	%	%	%	%	%	%	%	
A GREAT DEAL & A FAIR AMOUNT	21	21	23	21	22	17	21	1,823
NOT VERY MUCH & NOT AT ALL	79	79	77	79	78	83	79	6,903
Do you have reasons to complain about 'Damage done to the landscape'								
A GREAT DEAL & A FAIR AMOUNT	28	27	28	25	25	19	26	2,383
NOT VERY MUCH & NOT AT ALL	72	73	72	75	75	81	74	6,866
How concerned or worried are you about 'Species extinction'								
A GREAT DEAL & A FAIR AMOUNT	71	71	73	71	67	61	69	6,468
NOT VERY MUCH & NOT AT ALL	29	29	27	29	33	39	31	2,864

[1]Source: EuroBarometer 18, GESIS 1209, Oct 1982

extent. In 1987 fewer EC & GB residents aged 15–39 years felt the CAP could be supported if it provided environmental protection, or expressed support for incurring farming costs from less chemical use (Commission of the European Communities, 2012a) (Table 3.) - indicating less favour towards the environment. However, contradicting the idea of a youth disconnect from environment, in EuroBarometer in 1982 (Commission of the European Communities, 2012b) more EC young (15–44) felt that they had reason to complain about damage to the landscape than other age groups, and more of the young expressed concern about loss of species (Table 4.). Similarly more 18–34's, than other age groups, in Britain in 2000 and 2010 said that climate change is dangerous to the environment (Taylor, 2012).

Building works (for homes; roads; other building; & airports) are seen as the biggest threats to the UK countryside, in this GB survey. Otherwise the British public frequently mentions concerns about dumping, and threats to special areas or 'reserves' (Table 2.). Perhaps surprisingly, only 4% saw farming as a threat to the countryside in this survey, as between 1985 and 1999 in British Social Attitudes overall 65% to 74% agreed that 'modern methods of farming have caused damage to the countryside'. However, agreeing with the results here, only 5.1% of respondents did mention farming or agricultural pollution as threatening or spoiling the countryside in the British Social Attitudes survey in 1995.

There was also a surprising level of ignorance about the extent and contribution of farming in the UK. A majority of people (72%) felt that they do not know much, or know nothing, about the sector. That appears to be substantiated by the fact that most people dramatically underestimated the proportion of land used for farming, while overestimating its economic contribution.

Thus only 10% of respondents knew, to within plus or minus 10 percentage points, the actual amount of land that is farmed nationally in the UK. The mean estimation put forward by those taking part in the survey was about 35%. In fact, farming takes up about 75% of available land in the UK. On the other hand, the mean contribution of farming to the national economy was reckoned to be about 24% by most participants. In truth, farming contributed 1.5% of employment and 1.0% of GDP in 2011.

4. Conclusion

These data reveal evidence of a clear and widespread passion - or profound concern - for the British countryside, along with specific findings about the agricultural sector. A majority of people still visit the countryside more than once a month and 82% said it was either fairly important, or very important, for them to live within 30 minutes' striking distance of rural green space. Significantly, 73% of Londoners - many of whom do not live within easy reach of such areas - also felt this way.

Large numbers of the British people believe that farming is important for both the environment and for the economy, visit the countryside regularly and appreciate living near rural green space. Typically between 65% and 85% of the public hold these views. Levels of support were somewhat lower among those aged under 40, particularly the 18–24s and higher for those over 60 - which could be a concern if the trend continues. However, perhaps the smaller emphasis on farming and environment among younger people in GB reflects greater emphasis on current information among youth - as views of farming and environment, among younger cohorts, changed between EuroBarometer surveys in the 1982 and 1987.

The survey generally indicates a relatively high degree of support for farming and the countryside amongst the British public. They also overstate its economic importance. This might suggest a degree of acceptance of policies designed to give the sector support.

About the author

Mark Reader trained in Agricultural Science and Plant Physiology at the University of Western Australia, and worked, over the next 25 years, in a variety of posts in applied agricultural research in the UK, Australia, Peru and South Africa. His interests include: wellbeing; values and faith; farm performance; and public goods.

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The Groceries Supply Code of Practice: fairness for farmers?

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ABSTRACT

For many years the UK had heard complaints from farmers about the practices of supermarket chains. In 2008 the Competition Commission found that they had a point. In 2010 a Groceries Supply Code of Practice was established. Where there is a Code there is an Adjudicator. In 2013 the Adjudicator was given statutory authority to arbitrate disputes, investigate confidential complaints from direct and indirect suppliers, hold to account retailers who break the rules by 'naming and shaming' or, if necessary, imposing a fine. This article will look at this new rural view and consider the implications for consumers.

KEYWORDS: Competition Commission; Groceries Supply Code of Practice; Adjudicator's powers

Introduction

All across the western hemisphere the sound of farmers pleading that they are hard done by can be heard. But in the UK the Rule Makers have begun to take them seriously, acknowledging that they may have points to make. Key amongst them is the framework within which the arrangements they make with those who buy what they produce is regulated. This article will focus on the latest element of that framework, the Groceries Supply Code of Practice (the Groceries Code or GSCOP) and, as far as possible, include the farmers' voices.

What is the problem?

It is the inequality of bargaining power. Suppliers are many, supermarkets are few, market shares are huge.

In the UK in 2011 4 supermarkets commanded 76% of the supply of food products to consumers. In Austria in 2009 3 supermarkets commanded 82%. In Finland in 2011 5 supermarkets commanded 88%. In Portugal in 2011 3 supermarkets commanded 90% (Consumers International 2012).

The supermarkets, usually trading through stipulated processors and packagers, offer contracts that do not include prices. Produce can be over-ordered with confidence because the retailer will not suffer if it is not sold. This can be pernicious for soft fruit and salad growers, for example. Their entire year's income can be ruined by a cold grey UK springtime or a couple of rainy summer weekends when consumers will not buy summer produce.

The uneasy relationship between growers and these stipulated middlemen was colourfully illustrated by a former strawberry supplier called William Hudson:

"Everybody assumes growers have a direct line to the supermarkets, but that's not true. The real issue is with the marketing agents, middlemen and packers who do all the dirty work for the supermarkets. … The problem was when we were producing strawberries, there was never any negotiation - we were just told what we'd get for our supplies. … They are the schoolyard bullies in this system. … We have to question whether it's right when packers often make more money out of vegetables and packing than primary producers. … The primary producer lives in a world of cost and profit whereas the agency lives in a world of supply and demand. The supermarket only knows demand" (Case 2013).

There are some growers who supply direct to retailers. The criticised conduct of the sellers lies between them and those with whom they make contracts, be they intermediaries or producers.

This 'buyer power' combined with their 'retailer power' enables supermarkets to control their suppliers. It facilitates practices which might disconcert consumers, if they were aware of them.

They have been found (Competition Commission 2000) to include:

- Listing fees (charging to be on a list of suppliers)
- De-listing or the threat of de-listing (when suppliers refuse to reduce prices or make other payments and concessions backed by the threat of cutting them off)
- Slotting fees (where suppliers have to pay for shelf space)
- Demands for extra or unforeseen discounts or payments from suppliers (perhaps for marketing, store openings or remodelling, new packaging, and retailer-initiated promotions)

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- Demanding retrospective payments (perhaps consisting of extra discounts, after-sale rebates, percentage deductions of the total sales of a particular supplier's goods for that year, compensation for profit margins being less than expected; all commonly referred to as 'managing the retailer's profitability')
- Return of unsold goods to supplier (often at the suppliers' expense, including fresh produce that cannot be resold)
- Late payments (for products already delivered and sold)
- Retrospective changes to agreed terms (such as changes to quantity and/or specification without compensation)
- Below cost selling (often incorporated within unscheduled promotions to clear over ordered stock or to outsell rivals)
- Influencing product availability to, or raising the costs of, other retailers (usually by demanding lower buying prices than all other retailers or demanding limitations on supplies to other retailers)
- Promotion of retailers' own brands (resulting in the squeezing out of third-party brands. This may involve copy-cat packaging)
and
- requiring brand owners to divulge development intentions so that retailers can pass them on to their own brand suppliers.

This generalised overview is sometimes all that can be reported because individual suppliers are not prepared to be quoted. They are frightened. However, the UK newspaper 'The Observer' worked on this story for a month in June 2011 and persuaded a few producers to speak out (Renton 2011). Unlike in the newspaper, the supermarkets concerned are not named here.

Henry Dobell is a fruit farmer in Suffolk: "One year (the supermarket) refused all my raspberries after we'd picked and packaged them," he said. "So the producer organisation (the intermediary the supermarkets insist on dealing with) sold them to (another supermarket) and we had to buy new packaging. But they all went on as a two-for-one offer: we had no say. At one point we were being paid less per punnet than it cost to put a lid on it."

Michael Thompson is a chicken farmer in Devon: "Our problems started four years ago when the big egg packers merged, controlling about 60% of the market. There wasn't any competition any more and the prices started to go down, while everything else, like the feed price, was going up. I'd be getting 91p a dozen for large free range eggs, and it had been over £1. Meanwhile, my eggs were being sold for £3, while I was losing 15p on each dozen. … I did speak about it publicly. And the next time my eggs went for packing the number of seconds (eggs rejected as inferior) went up 5%. I can't prove this was done as a punishment, but I believe there was nothing wrong with the eggs."

Stewart Houston is a pig farmer in North Yorkshire: "Usually in pork, the processor deals with the supermarket and he should represent us. But you'll never get a processor disagreeing with a retailer. The supermarkets play them off against each other on price – and the retailers bear down on any attempt to get the price up … that's forcing producers out of business.... we've all been losing between £10 and £30 per finished pig."

Ray Brown is a dairy farmer in Cheshire: "Only a quarter of the people round here who were in dairy 15 years ago are still doing it. It's a wonder we've stayed in business. In 1997, we got 25p a litre at the farm gate. We're getting 26p now. But the price in the shops then was 42p a litre and now it's anything from 70p to £1. And we've seen all the costs go up.... You sign up to take whatever price the middlemen set and that can be retrospective. They might say, oh we're going to give you a penny less for June's milk, and there's nothing you can do about it. There's no negotiation." One farmer recently tried to instigate a Parliamentary debate[2].

A regional newspaper was told by an anonymous farmer from Waveney in Suffolk how his strawberry farm was driven to the brink of bankruptcy in the early 2000s after a supermarket at the top of the supply chain relentlessly drove prices down, leaving him with ever-dwindling profits. "The supermarkets set a price not in relation to the costs that suppliers have of producing food, but for what they think their customers will find an acceptable price for that product. … The only way the middle man can continue his business is by having continuity of supply to the supermarket which is their master. … So as a cheaper price is set by the supermarket, the cost of the price drop is passed to the middle man, who seeks to pass it on to the supplier. That means margins dwindle down the chain as each person along it tries to save money - and at the bottom are the food producers" (Eastern Daily Press 2012).

What has been done?

In 1999 the Office of Fair Trading (OFT) asked the Competition Commission (CC) to conduct an inquiry into complaints that supermarkets were abusing their market position in their dealings with suppliers. In 2000 they published their report (Competition Commission 2000), concluding that supermarkets were acting against the public interest, reducing the choice and quality of goods, and that a Supermarkets Code of Practice (Supermarkets Code) should be introduced. This Code was developed by the OFT and published for consultation in October 2001. It was formally introduced in March 2002.

A year later, the OFT launched a review, checking for leaks and effectiveness. This was completed in February 2004, concluding that it was not working effectively (Office of Fair Trading 2004). However, there were no recommendations for immediate action beyond further investigation and an audit of the supermarkets' records. In March 2005 the results of the independent audit were published, showing that supermarket practices had not changed significantly since the introduction of the Code, and that the position of suppliers had become weaker. The Code was not being used to resolve disputes.

The OFT has the power to order market reviews. In November 2004 Friends of the Earth, the Association of

[2] Phil Latham, a farmer, launched an e-petition about the plight of milk farmers in the summer of 2013. It attracted only 1,320 signatures. 100,000 are needed before a topic is considered for Parliamentary debate. *See* http://epetitions.direct.gov.uk/petitions/35798, [Accessed 5th September 2013]

Convenience Stores and the National Federation of Women's Institutes submitted a request for such a review of the grocery market, particularly including the position of suppliers. Nonetheless, and showing an awareness of the time these activities take, they stressed that revision of the Code need not to be delayed until the outcome of such a market review.

In August 2005 the OFT published its conclusions on the review of the Supermarkets Code (and some other competition concerns). It concluded that the Code should remain unchanged, but be used more effectively. They also declined to recommend a new market investigation into the grocery sector.

On the 3rd of October 2005 the Association of Convenience Stores (ACS) instructed Edwin Coe, a firm of London Solicitors, to launch an appeal to the Competition Appeal Tribunal over the OFT's refusal to call for a new market investigation.

On the 28th of October 2005 the OFT withdrew its previous decision, and agreed to reconsider referring the grocery market to the Competition Commission (CC) for a full review.

In February 2006 an All-Party Parliamentary Small Shops Group released a Report called 'High Street Britain: 2015'. It carried the warning that many small shops would go out of business if action was not taken to curb supermarket growth. The report called for a Retail Regulator and revisions to the Supermarkets Code. In March 2006 the OFT issued a preliminary ruling, recommending that a Competition Commission (CC) review of the supermarket sector be conducted.

On May 9th 2006 the OFT announced that it would, after all, refer the supply of groceries by retailers in the UK to the CC for a market investigation.

The CC stated in June that it would look at supplier issues, particularly whether the behaviour of grocery retailers towards their suppliers threatens the economic viability of suppliers or wholesalers, affects competition in grocery retailing, and affects competition among suppliers, for example by limiting the range of products. In July to September 2006 the CC conducted hearings with main and third parties. In January 2007 they published their 'emerging thinking' document, outlining the areas they intended to proceed with in the inquiry. In June they published a 'working paper on the Supermarkets Code of Practice' in which they acknowledged that many of the practices identified in the 2000 CC inquiry were still evident and that they are likely to have an adverse impact on competition.

In April 2008 the CC published its Final Report, concluding that supermarkets are guilty of transferring unnecessary risks and excessive costs onto their suppliers.

Amongst the proposed remedies the CC recommended a new Grocery Supply Code of Practice (GSCOP) to replace the existing Supermarkets Code of Practice and the establishment of a new Ombudsman to police it. Accordingly, in February 2009 the CC published its notice of intention to make an 'Order for the Grocery Supply Code of Practice'. In January 2010 the government announced that it would accept the CC's recommendation to establish a new supermarket ombudsman and in February 2010 the new Grocery Supply Code of Practice (GSCOP) came into force. The ombudsman morphed into the Code Adjudicator. Christine Tacon was appointed as the first Adjudicator in January 2013 and she took office on the 25th of June. No investigations will be conducted until she has published her Guidelines. That is expected at or by the end of 2013.

Looking at the highlights of this saga.

What did the first Supermarkets Code of Practice provide?

Seeking to put an end to the unjustifiable practices which had been identified by the Competition Commission (CC), the Supermarkets Code provided that:

- standard terms of business should be available in writing
- reasonable notice of variation of a supermarket's terms of business should be given
- there be no undue delay in payments
- there be no retrospective reduction in price without reasonable notice
- a supermarket should not directly or indirectly require a supplier to reduce the agreed price of or increase the agreed discount without reasonable notice

and so on. The Supermarkets Code set out to put an end to each and every one of the identified malpractices found by the CC in 2000. As the then Secretary of State for Trade and Industry, Patricia Hewitt, said: "The Code of Practice, with its independent dispute resolution procedures, will help to redress the balance between supermarkets and their suppliers. It will give suppliers greater certainty and security, by putting their contractual relations with supermarkets on a clearer and more predictable basis. … The success of the Code depends on supermarkets and suppliers being reasonable in their dealings with one another, and observing the spirit of the Code" (Department of Trade and Industry, 2001).

A centrally important element concerned the manner in which disputes would be handled. They were to be first considered by the parties to the agreement. If that failed then the supplier could take the case to an independent mediator. If that failed the case could be forwarded to the OFT's Director General by individual suppliers, or by their trade body if suppliers felt uncomfortable about approaching the OFT directly. The important point here is that the supplier and retailer had to try to resolve the matter first. Heads had to be put above parapets.

Who was covered?

The supermarkets supplying at least eight per cent of grocery purchases were required to give undertakings under the Fair Trading Act 1973, section 88, to comply with the Supermarkets Code. These were Asda, Safeway, Sainsbury, and Tesco. It was hoped that the other main players would also be involved in the process and comply with the code voluntarily. It applied to farmers who supply supermarkets directly or who use an agent. It did not apply to farmers who sell their produce to an intermediary (such as a dairy) which then sells to the supermarket, although it did apply to the intermediaries. It was, thus, based upon contractual relationships between the supermarkets and their direct suppliers.

Did it work? The OFT review in 2004

The Office of Fair Trading reviewed the operation of the Supermarkets Code and reported (the supermarkets code of practice) that they had found it impossible to draw any firm conclusions about how individual supermarkets were complying with the Code. Nonetheless they reported a widespread belief among the supermarkets' suppliers that the Code was not working effectively, and that it had not brought about any change in the behaviour of the supermarkets. The key reason they gave for this was fear of the consequences of complaining. Any code relies for its effectiveness on hard evidence, not merely anecdotal dissatisfaction amongst disappointed parties. The contribution of the supermarkets to the OFT review was that they were committed to the Code and that relations with their suppliers were generally good. They did add that their practices had not changed significantly since the introduction of the Code.

Seeking the missing evidence and noting both the extent of the general concern about the Code's effectiveness and the level of generalised complaints about the extent of compliance led the OFT to conclude that further investigation was required. Suppliers could or would not contribute with sufficient clarity, so an independent audit of the supermarkets' dealings with a sample of their grocery suppliers was commissioned from PKF (a global network of accountancy firms). It focussed upon those clauses in the Code where claims of breaches were most frequent and upon the supermarkets' handling of complaints from, and disputes with, their suppliers. The audit was based on a sample of 500 grocery supplier relationships with supermarkets, representing around 5% of all such relationships.

The audited clauses and findings were, first: 'terms of business to be available in writing'. Here suppliers were usually subject to the supermarkets' standard terms combined with additional particular terms which were recorded in various places such as trading agreements with suppliers, correspondence and promotional agreements. They noted that none of the sample of suppliers asked supermarkets for details of these particular terms, presumably because they were always aware of them or did not need or bother to ask for them. The second was, 'no undue delays in payment to suppliers'. Here, supermarkets usually paid when they say they would, although there was often added a 'processing time', and some suppliers were not aware of that. Third, that there should be 'no retrospective reductions in price without reasonable notice'. These 'discount clauses' were found in just under half of longer term agreements with suppliers and in connection with special promotions. Indeed, they were neither requested nor required for anything else. Such changes may be inevitable in such a competitive environment, but they carry a danger that an unfair proportion of risk is being carried by suppliers. The fifth concerned 'contributions to marketing costs'. Here such contributions appeared to relate to artwork and packaging, and that own-label rather than branded goods suppliers tend to bear the cost. The sixth concerned 'lump sum payments as a condition of stocking or listing a supplier's products'. Here, within the sample, 46 payments were demanded but 44 of those were by a supermarket that has been taken over by another, which makes no such demands. It was noted, however, that the fact that there is no record of suppliers complaining to supermarkets about such payments suggests that suppliers are unwilling to complain and, if necessary, use the mediation procedures provided under the Code.

Turning then to these supermarket – supplier disputes, the audit found only eight in five hundred cases where the Code provisions had been used to resolve disputes. Nonetheless, there was no hard evidence that disputes had been mishandled by supermarkets.

Overall, the audit found that, despite a few breaches, the supermarkets have generally complied with the Code. As if in surprise, it was also noted that the audit findings do not rule out the possibility that non-compliance may be more common than was shown.

The OFT reaction was to remind everyone that their doors remained open to discuss alleged specific breaches of the Code with suppliers and their trade associations on a confidential basis, and encourage trade associations to build up and submit dossiers of alleged breaches of the Code on behalf of their members. It seems clear that it was strongly suspected that the Code was being breached (or ignored) but that nothing much could be done without hard evidence. Further, that there was nothing that could be done by simply amending the Code or indeed introducing any other measure which would remove the fear of complaining. Further, they were sceptical whether the simple step of introducing of a different form of dispute resolution could address the root cause of the fear, the inequality of bargaining power between the supermarkets and many of their suppliers, and the overriding need felt by many suppliers not to jeopardise trading or, more simply, just to stay in business. They stressed that no code can be effective in dealing with allegations of breaches unless evidence of those breaches comes forward.

The overall view was that it is legitimate for supermarkets to compete vigorously for supplies on terms that provide good value in respect of price, quality and other characteristics. Competition between supermarkets benefits consumers and encourages efficiency and innovation through the supply chain. It is to be expected that both supermarkets and suppliers want the flexibility to be able to make changes to agreements in order to run promotions or respond in other ways to the forces of competition. However, the OFT viewed it neither legitimate nor fair for a retailer to negotiate terms and then unexpectedly and unilaterally seek to change or cancel them.

The OFT's cry for evidence was heard and answered by the press in the farming and retail sectors (again, not naming the retailers here.)

A supplier (to a major retailer) wrote to the Grocer in February 2003 (The Grocer, 2003b) alleging that (they) made "demands for six figure payments" which, according to the supplier, would breach the Code of Practice. But the letter went on to say that the supplier felt they could not go to the OFT about this as doing so "would damage their business even more". … another supplier commented that "I would get blacklisted instantly" (The Grocer, 2003a).

Others have pointed to the vagueness of the Code, in particular to the references to 'reasonable' practices. As one supplier pointed out, "If you are a small supplier negotiating with a retailer who has more than 15% of the market, you can bet it's not you who defines what is 'reasonable'… if you don't like it you can lump it" (The Grocer, 2002).

It is not surprising then that only one official complaint, from Express Dairies, had been received by the OFT. This asserted that a retailer had unreasonably failed to give adequate notice of its decision to cease taking supplies of fresh milk. Even this single complaint was not dealt with because it concerned a supply contract that had been made before 1 November 2001 and was therefore outside the scope of the Code.

The Competition Commission's Final Report in April 2008

Amongst its proposed remedies the CC recommended a new Grocery Supply Code of Practice (GSCOP) to replace the existing Supermarkets Code of Practice and the establishment of a new Ombudsman to police it. Accordingly, in February 2009 the CC published its notice of intention to make an 'Order for the Grocery Supply Code of Practice'. and on 4th February 2010 the new Grocery Supply Code of Practice (GSCOP) came into force.

In January 2010 the government announced that it would accept the CC's recommendation to establish a new supermarket ombudsman. Predictable arguments followed. Supermarkets said that the fact that there have been no referrals to arbitration under GSCOP since it came into force in February 2010 shows how fair their treatment of suppliers is. Those in favour replied that it proves how cowed suppliers are by the power of the retailers.

Supermarkets said the administration of the system will push up costs and bring unnecessary burdens. The reply was that the costs are minimal in comparison with their profits and further, that if their suppliers are being treated fairly, arbitration will be very rare and therefore result in little additional work or cost.

Supermarkets said if GSCOP is doing its job already and there is going to be no work for the adjudicator, why have it in the first place? The reply was that it is needed to help suppliers raise grievances without fear of reprisals by the retailers, that it was recommended by an extensive CC investigation and that it has deterrent value.

Who is covered by the new Code (GSCOP)?

The Groceries Code applies to the 10 UK retailers with a turnover in the groceries market in excess of £1bn[3]. They are Tesco, Asda, Sainsbury's, Morrisons, Waitrose, Marks & Spencer, Aldi, Lidl, Iceland and the Co-op. It applies to farmers who supply supermarkets directly or who use an agent. It does not apply to farmers who sell their produce to an intermediary (such as a dairy) which then sells to these 10 supermarkets, although it does apply to those intermediaries. It applies to these retailers and their direct suppliers.

What does the new Code (GSCOP) provide?

Beyond any voluntary code of practice, or 'assurance' to the OFT, GSCOP requires large retailers to:

> deal fairly and lawfully with their suppliers, not vary supply agreements retrospectively (except in circumstances beyond the retailer's control which are clearly set out in the supply agreement), pay suppliers within a reasonable time, to pay compensation for forecasting errors in certain circumstances and to take due care when ordering for promotions. The retailers included here (the Designated Retailers) are prohibited from entering into or performing any supply agreements unless that supply agreement incorporates GSCOP, and does not contain any provisions that are inconsistent with GSCOP. The effect of this is that the Code becomes part of the terms and conditions and if broken, may amount to a breach of contract.

Further, it limits the power of the Designated Retailers:

> to make suppliers change their supply chain procedures, to make suppliers pay marketing costs and compensation for wastage, to make suppliers obtain goods or services from third parties who pay the retailer for that arrangement, to make suppliers pay them for stocking their products, to make suppliers pay for promotions and to make suppliers pay for resolving customer complaints. Finally it limits their power to 'de-list' suppliers, that is, to stop dealing with a supplier or make significant reductions to the volume of purchases from a supplier (Department for Business, Information and Skills 2013).

Much of this is familiar. It does, however, have a specific statutory footing this time and that may make a difference. However, what may be more productive is the acceptance of the Competition Commission's recommendation, the legislative steps taken and the appointment of a kind of ombudsman, the Code Adjudicator, to police the process. The necessary Bill received Royal Assent on the 25th April 2013, thus becoming the Groceries Code Adjudicator Act 2013. It came into force on the 25th of June 2013.

The Groceries Code Adjudicator can: arbitrate disputes between retailers and suppliers, investigate complaints from suppliers, name and shame retailers who break the rules and impose fines in the worst cases. This last option was resisted and received a mixed welcome. British Retail Consortium director-general Stephen Robertson said: "The power to impose fines is unnecessary and heavy-handed, and should be kept in reserve. … The code already has a provision for naming and shaming retailers, and in the 2.5 years it has been operating not one supplier has needed to go to arbitration to resolve a problem with a supermarket." Whereas the Forum of Private Business head of policy Alex Jackman said: "Supermarkets understand one

[3] In early September 2013, £1bn was approximately equivalent to $US1.57bn and €1.19bn.

thing and one thing only, and that's money. So it's just common sense for the adjudicator to be able to wield this kind of weapon as a measure of last resort in the worst cases of malpractice'' (McEwan 2012).

But perhaps the most important development within this framework is that the Grocery Adjudicator will be able to use evidence from third parties (such as indirect suppliers like farmers and from whistleblowers and various trade associations) to initiate investigations into alleged unfair practices by supermarkets. It may now be possible for those who claim that they have been so adversely affected by retailers' practices that the Code has seemingly been breached to have the Adjudicator step in without having to raise their heads above the parapet. Of course, it may be difficult to hide if the supplier makes a unique contribution. Nonetheless, the Adjudicator cannot make unauthorised disclosures of information relating to arbitrations or complaints brought by suppliers where that disclosure might identify the complainant supplier. Whilst third party information can be received in confidence, it is important to be clear that the GSCOP only applies to the dealings between the Designated Retailers and their direct suppliers and so a dispute between a farmer and an intermediary would not be covered, but a farmer supplying directly or using an agent would qualify.

Perhaps predictably, this access for third parties has drawn comment. The British Retail Consortium food director, Andrew Opie, said that this would ''open retailers up to malicious campaigns and fishing expeditions from those without full knowledge of the agreements involved, at a great cost to all parts of the grocery supply chain''. Whereas NFU President Peter Kendall said the Government's ''strong stance against an intense lobbying campaign by retailers'' was a ''just reward for the farmers and growers who had bravely stepped forward amid a climate of fear to reveal the unfair practices that were confirmed during the two major investigations carried out by the Competition Commission'' (Farmers Guardian, 2012).

Beyond investigations, the Adjudicator will be advising suppliers and Designated Retailers on the scope of the GSCOP and publishing guidance about the criteria, practices and procedures which will be adopted by the Adjudicator in deciding whether to conduct investigations, in carrying them out and in relation to enforcement action. There will be no investigations launched until after a consultation exercise and the publication of finalised guidance. This is expected at or by the end of 2013. The Adjudicator will produce an Annual Report. Incidentally, there will also be a levy on the Designated Retailers to fund the Adjudicator's expenses. That has not proved to be a popular move.

More farmers as direct suppliers

Over the past few years there has been an increasing emphasis placed by the major supermarkets on sourcing their produce locally. In response to a journal article criticising the environmental damage of transporting food long-distances, and suggesting that people should try to buy food from within a 20km (12-mile) radius, (Pretty *et al.,* 2005), the supermarket spokesmen were heard. A Tesco spokesman said the company was "committed to trying to source locally whenever possible, the seasons allow and there is customer demand". Asda said it has a dedicated local sourcing unit that is separate to its main sourcing department. "Across the UK we have 200 local suppliers, many of which are very small indeed, employing less than 20 people. … We try and make it as easy as possible for small firms to supply to us." Waitrose has a Small Producers' Charter. They say ''we have always looked to source products from areas within which we trade, but we want to work with more small, local and regional suppliers'' (Waitrose 2013).

A spokeswoman for Sainsbury's said it was "aware that many of our customers want to buy local products which reflect regional tastes and traditions and have a preference for food grown or reared locally. … We are committed to giving our customers the diverse range of local foods they want and have a dedicated team who search for promising local producers as part of our local sourcing programme." A spokeswoman for Morrisons said it was a "keen supporter of small, local and regional producers and have a number of local producers supplying our stores" (BBC News (2005).

The Campaign to Protect Rural England ran a campaign in the spring of 2013 to encourage supermarkets to support local producers. They said: ''Nearly all of them stated a commitment to support British farming, and some use cost of production business models to agree prices with the farmers they trade with'' (CPRE 2013).

So perhaps more farmers will become direct suppliers and obtain the protection, such as it may be, of the GSCOP.

And, in the end…

Consumers shop at supermarkets. The Cassandra warnings of the loss of small producers and outlets, the 'use it or lose it' voices, are heard but not always noted. We have a complex relationship with supermarkets. They provide constant consumer choice often at remarkably low prices. They supply an outlet for the best of British produce. But they are accused of driving small, independent shops out of business, and small farmers with them (although some have thrived as suppliers). Consumers may pay regard to the interests of these small-scale farmers and their local produce. They may have sympathy with the diminishing farming community. They may decide to shop more locally, to visit farmers' markets and small stalls. But the supermarket 'store wars' are a strong draw. With a reasonable income the convenience of a large store with easy and free parking is attractive. With a large family and a small income it's a luxury to be able to plan forward at all.

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The 'wickedness' of GM crop applications in the European Union

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ABSTRACT

The European Union (EU) still retains genetically modified (GM) crop applications within its agriculture and on the EU market. The current EU non-GM crop regime is in fact a 'fictitious' or 'virtual' non-GM crop regime that has developed into a 'wicked' problem. Any progress towards resolving this impasse, either in favour of or against GM crops and their applications, is extremely difficult due to the inherent nature of the problem and the high level of conflict, discord and complexity involved. Top-down decisions are ineffective as a solution, which was clearly demonstrated by the failure to induce change when the GM potato Amflora was resolutely authorised for cultivation in the EU. True solutions require multi-level stakeholder engagement and a common understanding of a shared problem to break the impasse in the EU. Reaching this shared understanding remains a major - albeit interesting - challenge for future research.

KEYWORDS: Genetic modification (GMO, GMI); EU; regime; wicked problem; shared understanding

1. Introduction

European consumers have become increasingly disconnected from the agricultural practices and the production chain that actually produces their food. This disconnection generates a high dependency on other stakeholders and implies that if an agricultural practice is not part of the societal debate, we often take it for granted.

For a non-governmental organisation (NGO) social engagement is necessary to exert power. As NGOs are strongly opposed to genetically modified (GM) crops from an ideological standpoint, they have made GM crops a 'socially sensitive' innovation in the European Union (EU). Some authors argue that this successful public mobilisation relied on shared values across the majority of European citizens, while others describe the anti-GM front (and especially NGOs) as advocacy groups who impose their ideological opinions on society. Although there is no evidence of a direct cause-effect relationship, campaigns by NGOs (combined with media coverage) have indeed affected the overall EU public perception of GM crops and their applications. At present, Europeans are highly sceptical and restrained, and EU supermarkets openly refuse the use of genetically modified ingredients (GMI) in their stores.

2. Yes, we do eat GM food in the EU

Although GMIs must be labelled in the EU, most EU consumers are unaware of the fact that many GMIs are actually present in EU supermarkets and in the foods that they consume. For example, eggs, milk or meat derived from GM-fed animals are sold on the EU market without a GM label (as these animal products are exempt from GM labelling under Regulation EC 1830/2003). Plant-derived processed food products may also contain GMIs at traces below 0.9%, as amounts below this threshold are also exempt from GM labelling under this Regulation. Hence, the non-GM regime in the EU market is only a 'fictitious' or 'virtual' non-GM regime. Clearly, this creates a tricky and challenging environment for EU supermarkets to conduct business, as the indirect presence of GMIs in their stores prohibits them from correctly claiming that they are 'GM-free' while it simultaneously inhibits them from publicly doubting the safety of GM crops.

At present, the EU GM crop legislation is one of the most stringent worldwide, yet unpredictable and vulnerable to shifts in public opinion. To date, this regulatory environment has failed to create a stable and predictable environment in which to research, regulate and implement GM crop applications. On a political level, for instance, individual Member States (MS) actively build and exploit a non-GM identity. They may implement co-existence measures that do not necessarily comply with the available scientific evidence but that create a 'GM-safe' country image (Ramessar *et al.*, 2010). Or they implement a national regulation to specifically market their non-GM identity, such as the labels 'Gentechnikfrei' in Austria, 'ohne Gentechnik' in Germany and 'sans OGM' in France. In addition, several MS, such as Austria, Luxembourg, Poland and Germany, have installed an official ban on MON810 cultivation on their territory (which is the only GM maize currently authorised for cultivation in the EU). These 'GM-free identities' reinforce the present

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fictitious EU non-GM crop regime, yet they somehow conflict with other European and international legislations that focus either on risk, safety and biodiversity or on free trade mechanisms, in terms of their assessment and decisions with regard to GM crops.

Many authors doubt whether the current non-GM crop regime in the EU will persist in the future, as at present GM crops are rapidly implemented outside the EU whilst a deadlock situation has developed within the EU. This disparity compromises the availability of non-GM certified raw materials (especially vegetable proteins) that the EU needs to import. Also, the new GM crops in the pipeline are quite diverse in terms of their characteristics and applications. New GM crop applications are expected to increase substantially in Asian countries, and this will reduce the attractiveness of producing non-GM crops for the European market. It is therefore of interest to determine how the EU regime will cope with these future trends.

3. A wicked problem

The current deadlocked non-GM crop regime in the EU can be classified as a 'wicked' problem, defined as having:

> *'cause-effect relationships that are difficult or impossible to define, cannot be framed and solved without creating controversies among stakeholders, and requires collective action among societal groups with, strongly held, conflicting beliefs and values' (*Dentoni *et al,* 2012*).*

GM crops directly impact on our agricultural and consumption practices and hence potentially impact on the cultural meanings attached to our food production and consumption. Therefore, many stakeholders to-and-fro position themselves dynamically and in different constellations in the GM debate. The wickedness of the problem, though, makes this debate very complex and includes many social issues, such as the globalisation of agriculture, the patentability of life forms, the role of science in society, the future of the common agricultural policy and the power of multinational industries.

However, solving a wicked problem is extremely difficult, due to the high level of discord and complexity involved. Attempts to solve such a problem cause unforeseen consequences or side effects. Top-down decisions simply do not work when addressing a wicked problem, as true solutions require multi-stakeholder engagement and a common understanding of a shared problem. That is why, for example, the decision by the European Commission to (resolutely) authorise the GM potato Amflora for cultivation in the EU was deadlocked within two years, as the agricultural biotech company BASF ceased to market the GM potato any further due to social resistance. Notably, this authorisation has now been annulled by the European Court of Justice (in December 2013), as the Commission departed from the rules of the EU authorisation procedures.

4. GM crops are a wake-up call

Currently, one of the highest values of GM crops is their ability to challenge the basic social, political and cultural principles of our 21st century EU society. For instance - do we support or oppose globalised agriculture?; do we accept a vertical power distribution in our food supply chain?; do we accept public-private partnerships in fundamental research funding? From the perspective of a wicked problem - which cannot be solved, but only managed - these dilemmas and tensions are valuable, as they help organisations and communities to reaffirm their roots and express their desires about the future. So, regardless of whether GM crop applications are implemented on a larger scale, or not, they have generated discussions that matter within the EU.

In the US, GMIs are standard within conventional products and consumers that repudiate GMIs are forced to buy organic products as the best alternative. Yet, this seemingly stable GM crop regime in the US is currently wavering because obligatory GMI labelling of American food products receives considerable public attention through initiatives such as California's Proposition 37 or Initiative 522 in Washington. Thus it is not the actual GM crops or GM foods that constitute the wicked problem, but the accompanying regime that institutionalises this agricultural innovation.

5. The way forward

The present non-GM crop regime in the EU is a wicked problem and GM crop applications are deadlocked as a result. To move forward implies unlocking the present impasse, either in favour of or against GM crop applications. This requires a shared understanding of the values, risks, opportunities and problems relating to GM crops and their applications.

Generating this shared understanding is a highly complicated trial-and-error exercise, as the debate revolves around many, often intertwined, issues which are approached with sometimes opposing scientific evidence, perceptions and interpretations. Moreover, the stakeholders involved have to look for complementarity instead of focusing on distinction. For example, from an industrial perspective, agribusiness companies must focus on action instead of caution, and they must define a long-term vision instead of just anticipating. Consumers must better understand the process of agriculture and food production, and politicians must either fully acknowledge the consequences of a globalised EU agriculture or they must prioritise its complete self-supportiveness. However, reaching this shared understanding of GM crop (applications) in the EU is still a major - albeit interesting - challenge for future research.

About the authors

Linde Inghelbrecht obtained a pre-doctoral FWO fellowship for a PhD at the Department of Agricultural Economics at Ghent University, in collaboration with the Social Sciences Unit of the Institute for Agricultural and Fisheries Research (ILVO). Her PhD focusses on understanding the present (non-) GM crop regime in the EU, and on formulating possible ways forward (either in favour of or against GM crop applications).

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Application and comparison of risk adjusted performance-indicators in the context of pig production

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ABSTRACT

In the recent past, risk and risk management in agriculture has risen on the agenda of farm managers. Amongst other things, the increased interest is inter alia attributed to the Capital Requirements Directives in the 'Basel II' agreement. In this article, we apply indicators of risk-adjusted returns, well known in the valuation of equity funds, to the context of pig production. Using a large data set of pig farm performance data, we demonstrate that different indicators of risk-adjusted returns do not necessarily lead to different results in the valuation of farms. We recommend using the Treynor Ratio in practical application. Our empirical analysis did not reveal a significant relationship between returns and risk.

KEYWORDS: performance measurement; risk measurement; risk-adjusted returns

1. Introduction

Risk in agricultural businesses is often discussed in the context of default risks, e.g. as a result of poor harvests. Instruments such as insurances or weather derivatives have been developed to address this type of risk at the farm level. A standard rule in the finance world stipulates that higher risk must be compensated for by higher expected returns for the investor. On the other hand, the investor[4] must accept higher-than-average risk if he expects higher-than-average returns. Accepting above-average risk with average returns would be inefficient.

There are well established measures in the financial sector for quantifying an investment's performance. Performance measurement in this context means that the success of an investment fund or its manager is not only measured by the fund's average returns but also by the risk associated with it. An investment's risk is generally a complementary decision criterion to the investment's average return (Perridon, 2004). This means, that increasing returns normally goes hand in hand with increasing risk.

During the past decades, a number of performance indicators have been established which combine returns and risk in one figure. Returns are usually represented by excess returns and risk is mainly represented by a measure of the return's volatility.

The aim of this paper is to apply the performance indicators developed in the financial sector to the performance measurement of pig production and to identify the most appropriate performance indicator to measure a pig farm's risk-adjusted returns. Appropriate performance indicator should be applicable as a success criterion in business consulting and as a basis for intercompany comparison. Particularly in the area of credit financing, farmers are facing increasing challenges. These result in part from tighter requirements imposed by banks (e.g. as a result of the Capital Requirements Directives 2006/48/EG – Basel II) but also from increasing price volatility on input and output markets. The 'Landwirtschaftliche Rentenbank[5]' explicitly recommends employing consulting organizations as a mediator between banks and farmers in financing issues (Landwirtschaftliche Rentenbank, 2010). Consulting organizations thus need appropriate indicators that do not only reflect the operating returns but also include a measure of risk.

Such extended performance indicators are however not only of interest in the context of debt financing. Knowledge of the degree of volatility is also important in controlling income tax in the light of the lacking opportunity for farmers, at least in Germany, to forward profits or losses to subsequent fiscal years.

Against this backdrop, this article aims to answer the following specific questions:

- To what extent is it possible and useful to transfer the performance indicators typically used in the financial sector to the context of pig production?
- Do the different performance measures generate different results?

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[4] An investor can be everyone providing equity or debt to a company (e.g. owners, banks, but also any other person or institutions investing money in a company)

[5] 'Landwirtschftliche Rentenbank' is a German bank that promotes projects and investments in the agricultural sector.

- Which of the combined performance measures is the most appropriate one for the purpose of business consultation and bank-farmer mediation?
- Can a relationship between risk and returns be identified in the context of pig production? Is there a tendency that risky enterprises generate higher returns?

The following Section 2 reviews the literature and explains how the success of farms might be assessed by the different measurement concepts typically used in the financial investment sector. Section 3 sets out alternative measurements of risk and returns. Based upon these, Section 4 defines and explains alternative performance indicators combining returns and risk in one figure. Section 5 presents empirical estimates of the alternative risk-adjusted performance measures using a large data set from pig fattening enterprises. We investigate whether the different performance measures generate different results and assess their suitability for practical application. This is followed, in Section 6, by an empirical investigation of a possible relationship between the level of risk and returns in pig fattening. The final section discusses the results and concludes.

2. Literature

There is a vast literature on risk and risk management in agriculture. In the field of hog fattening, risk relates to the volatility of input and output prices and to the biological performance of the animals. The broader literature on risk in agriculture is mainly driven by the question of how the various risks can be predicted and managed. Hardaker *et al.* (2004) provide a comprehensive overview of methods of agricultural risk management and risk prediction. The methods presented there primarily focus on methods for decision-making under uncertainty and the simulation or prediction of risks. Methods such as stochastic simulation or decision trees are used to predict, simulate and manage risk. Lien (2003) uses stochastic simulation to identify important factors relating to the financial risk of Norwegian dairy farms.

Weber *et al.* (2008) illustrate the possibilities of minimizing risk through insurances and hedging instruments for arable farms. The instruments compensate the financial loss when a possible risk occurs. While these instruments do not affect the likelihood of a risky event occurring, they are designed to mitigate the (negative) financial effects associated with the occurrence of such an event: risk is managed.

The present paper, however, focuses on the benchmarking of farms taking risk aspects into account. Benchmarking of companies is usually based on the idea of efficiency. Analyses in that context use, for example, Data Envelop Analysis (DEA). DEA aims to identify productive units that are efficient and to rank inefficient units relative to the efficient ones. In the context of risk and returns, a firm is always more efficient when it is more profitable at the same level of risk or when it is less risky at the same level of profit. Tiedemann *et al.* (2011) apply DEA to investigate whether consideration of risk (fluctuations in output) changes the performance evaluation of farms compared to measures that only consider averages. They find that this is indeed the case. Diversified farms achieve on average a higher efficiency score when the fluctuations of the gross margin are taken into account. Consideration of risk may thus lead to a different assessment of that company's success.

The goal of our work is to develop a set of standardized performance measures that can be used to compare the performance of pig fattening farms. All of these measures aggregate risk and returns in one figure, albeit in a different way. Markowitz (1976) was the first to introduce a concept for the evaluation of investments which combines these two factors. While the measurement of returns is largely unproblematic, there are various ways of measuring risk. This has given rise to the development of a plethora of indicators that measure risk-adjusted returns or performance in one figure. An overview of these different measures is given by Christopherson (2009) or Knight (2002). These performance measures have been used in the finance industry for some time to evaluate investments. Basically, these performance measures can also be used for any other investment. However, the authors are not aware of applications of these measures in the context of agriculture.

3. Measuring returns and risk

Performance indicators consist basically of the two components risk and returns. In the classical measurement of a portfolio's performance[6], returns represent the 'change in wealth' (Bacon, 2004). For the purpose of this paper, we compute 'returns' as the excess return of a single farm over and above the market return on the basis of gross margins. Gross margin is defined as the difference between revenue and variable costs of an enterprise. Gross margin thus disregards fixed and overhead costs. It thus falls short of a comprehensive criterion for the operating result of a pig producer, but it is a strong indicator of a farm's success in marginal costing. Nevertheless, it must be kept in mind that fixed and overhead costs may still lead to a negative operating result.

Measuring returns

Rather than measuring returns in absolute terms, the annual return of a farm (R_i) in this paper is computed as the share of gross margin in the farm's proceeds as per the following equation:

$$R_{\mathrm{i}} = 1 - \left(\frac{fc + d + pc + ec + mc}{p}\right)$$

R_i is the share of the gross margin in proceeds (p). The following cost types (annual sums per farm) are taken into account: fc= feed costs, d= dues[7], pc= piglet costs, ec= epidemic insurance costs, mc= miscellaneous costs.

The annual market returns (R_m) are computed as the share of the sum of all farms' gross margins in all proceeds in any given year (Figure 1).

The average return of the farms ($\overline{R_i}$) and the market ($\overline{R_m}$) across all years (1999 through 2010) are computed as the geometric mean of the annual returns R_i and R_m.

[6] A portfolio is a collection of investment assets. In the context of this article all farms in the dataset.

[7] E.g. for consulting and insurances.

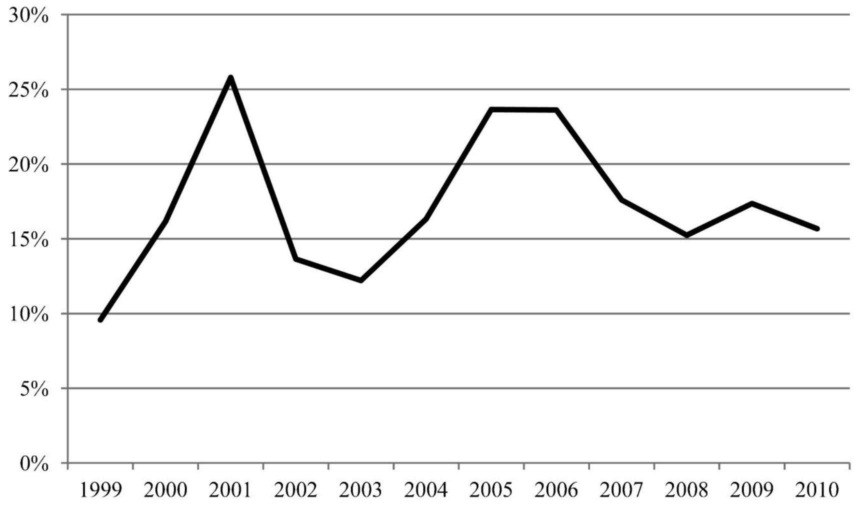

Figure 1: Annual market returns R_m (n=159)

The difference between $\overline{R_i}$ and $\overline{R_m}$ is excess return (*ER*) or, more generally, the difference between the performance of a farm and the performance of the portfolio (mean of all farms in the data set).

Measuring risk

The risk measures presented in this section are based on the mean and the variance of returns. In the context of this paper, these are based on the mean excess returns (ER) and the volatility of these excess returns. These mean-variance approaches have been criticized in the literature for not adhering to the theoretical requirement of returns being normally distributed (Leland, 1999; Eling *et al.*, 2010). For this reason, tailor-made performance measures have been developed that take higher moments of distribution (such as skewness and the kurtosis) into account. Eling *et al.* (2007, 2010) investigate several performance measures based on logistically distributed hedge-fund's returns and note very high rank correlations between traditional and tailor-made performance measures, indicating that normally distributed returns do not seem to be a prerequisite for practical purposes.

Standard deviation and variance

A basic measure of risk is the standard deviation (σ_i) or the variance (σ_i^2) of the returns on investment. These measures of volatility can be used to identify for example maximum losses or gains to be expected in a particular confidence interval of distribution. This information can also be used to identify how often good or bad events might occur (Christopherson, 2009).

Markowitz (1976) introduces the semi-variance and semi-deviation in the context of portfolio theory. Semi-variance subdivides the overall variance of an investment's returns into good (i.e. upside) and bad (i.e. downside) variance. Returns above the mean create upside variance and should not be considered as risk. Only returns below the mean – downside variance (σ_{id}) – should be taken into account when calculating the variance in the context of risk measurement.

The methodology to calculate downside variance is called lower partial moments (LPM). Downside variance is a special case of LPM where the deviation is raised to the power of 2 and the target return is set equal to the mean return of the market (Christopherson, 2009):

$$\sigma_{id} = \frac{1}{n}\sum_{i=1}^{n} d(x)(R_i - R_m)^2$$

with

$$d(x) = \text{function that returns 1 or 0;}$$

$$d(x) = \begin{cases} 1 \ \mathit{if} \ R_i \leq R_m \\ 0 \ \mathit{if} \ R_i > R_m \end{cases}$$

Skewness and kurtosis

Another indicator of risk is the ratio of downside variance and total variance of an investment. The ratio is represented by the skewness and the kurtosis of the distribution. An asymmetric distribution with a positive skewness indicates that there is a tendency to more upside variance. Negative skewness, by contrast, indicates a predominance of downside variance (Christopherson, 2009). The larger the kurtosis of the distribution, the more pronounced the positive or negative drift.

Beta

Beta reflects the systematic risk of an investment. Beta measures an investment's volatility relative to the market's volatility. Beta is based on the idea that the returns of a stock, portfolio or farm are highly correlated with the respective market returns. Beta measures the sensitivity of the stock's, portfolio's or farm's returns to market returns by relating the covariance of individual and market returns to the market return's variance (Fischer, 2001):

$$\beta = \frac{Cov\ (R_i, R_m)}{\sigma_m^2}$$

where $Cov\ (R_i, R_m)$=Covariance of R_i, R_m and σ_m^2= Variance of R_m.

In this article, market returns are represented by the average return of all farms. In other contexts, market

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returns can also be represented differently, for example by the return of a stock index. A beta of greater than 1 indicates that the stock's (or farm's) returns are more volatile and therefore more risky than the market returns (Fischer, 2001).

Tracking Error

The Tracking Error (TE) is similar to the standard deviation of returns. Instead of the return's standard deviation, the Tracking Error measures the standard deviation of the excess returns (Amenc, 2003):

$$TE = \sigma(R_{\mathrm{i}} - R_m)$$

Value at Risk (VaR)

Value at Risk estimates the maximum loss to be expected during a period within a certain confidence level. A one-year 99% VaR of £-5.000 means that the investor can be 99% confident that he does not lose more than £5.00 within the next 12 months. There are three different ways of calculating VaR.[8] In the present paper we use a special case of the so-called parametric VaR. The 'normal' parametric VaR is calculated as:

$$VaR_{parametric} = \overline{R_i} + Q_d\ \sigma_{\mathrm{i}}$$

with Q_d representing the percentile of the normal distribution. Since some data is not normally distributed, Favre *et al.* (2002) suggest using a 'Cornish-Fisher approximation' to adjust the parametric distribution by taking the third and fourth moment, skewness and kurtosis, into account in order to approximate the empirical distribution (Lhabitant, 2004). This methodology is referred to as modified Value at Risk (mVaR).

$$mVar = \overline{R_i} + \left(Q_d + \frac{Q_d^2 - 1}{6} S_d + \frac{Q_d^3 - 3Q_d}{24} K_d - \frac{2Q_d^3 - 5Q_d}{36} S_d^2\right)\sigma_{\mathrm{i}}$$

with
Q_d= Quantile of the normal distribution
S_d= Skewness of the return's distribution
K_d= Kurtosis of the return's distribution

4. Risk-adjusted performance measures

Based on the previously presented measures of risk and returns, several performance indicators have been developed. The measures differ in some preconditions and assumptions and especially in the way risk is measured.

Sharpe Ratio

The most popular performance measure is the Sharpe Ratio, which measures the ratio of excess return and standard deviation of returns (Amenc, 2003):

$$Sharpe\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\sigma_{\mathrm{i}}}$$

Application of the Sharpe Ratio is not without controversy though, because it requires normally or at least elliptically distributed returns.

Sortino Ratio

The Sortino Ratio was developed against the background of non-normally distributed returns. In contrast to the Sharpe Ratio, the Sortino Ratio only uses the downside deviation as risk measure (Bacon, 2004):

$$Sortino\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\sigma_{\mathrm{id}}}$$

Treynor Ratio

The Treynor Ratio was developed by Treynor (1965) to measure risk-adjusted returns of different portfolios by a standardized measure. The Treynor Ratio only measures the systematic risk of an investment – represented by β, but not the total (market) risk (Weingärtner, 2009):

$$Treynor\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\beta}$$

with $\beta = \frac{Cov(R_{\mathrm{i}}, R_m)}{\sigma_m^2}$ as per above

Information Ratio

The Information Ratio uses the Tracking Error (TE), which is the standard deviation of the excess returns, as risk indicator. The Information Ratio is similar to the Sharpe Ratio. As a risk indicator, however, the Tracking Error makes use of the standard deviation of excess returns rather than of total returns (Bacon, 2004).

$$InformationRatio = \frac{\overline{R_i} - \overline{R_m}}{TE}$$

Risk-Adjusted Performance (RAP)

The RAP was developed by Franco and Leah Modigliani in 1997 as a performance measure that is intuitively understandable. It is also known as M^2, M2 or Modigliani-Modigliani measure. The RAP measures the risk-adjusted return of an investment relative to a given benchmark. The measure implies that a risky investment should generate higher returns than the market's average returns (Knight, 2002; Amenc 2003):

$$RAP = \frac{\sigma_m}{\sigma_i}\left(\overline{R_i} - \overline{R_m}\right) + \overline{R_m}$$

where σ_m is the standard deviation of annual market returns and σ_{i} is the standard deviation of the investment's returns.

Modified Sharpe Ratio

The Modified Sharpe Ratio takes into account the issue of non-normally distributed returns. In contrast to the Sharpe Ratio, risk is represented by the modified Value at Risk (mVaR). The mVaR takes the first 4 moments of the distribution into account in order to correctly estimate the empirical distribution (Gregoriou, 2004):

[8] Parametric Var, historical simulations and Monte Carlo simulations.

Table 1: Comparison of the different performance measures

Performance measure	Preference Driver	Distribution Assupmtion	Risk measure	Inter market comparability
Sharpe Ratio	Mean Variance	Elliptical	Overall variance	yes
Information Ratio	Mean Variance	Elliptical	Variance of excess returns	yes
RAP	Mean Variance	Elliptical	Overall variance	yes
Sortino Ratio	Downside Variance	Assymetric	Overall downside variance	yes
Treynor Ratio	Mean Variance	Elliptical	Systematic risk	no
Modified Sharpe Ratio	Extreme loss aversion	Assymetric	Expected losses	yes

Table 2: Descriptive Statistics of the Dataset (N=1908, equivalent to 159 farms over 12 years)

	MEAN	Std. Dev.	MEDIAN	MIN	MAX
proceeds	358,554.78 €	321,436.38 €	281,819.00 €	29,159.02 €	4,530,712.00 €
share of dues deducted from proceeds	0.49%	0.28%	0.43%	0.03%	2.76%
share of piglet costs deducted from proceeds	43.79%	5.54%	44.02%	21.46%	64.13%
share of feed costs deducted from proceeds	35.85%	7.16%	35.21%	19.11%	90.22%
share of epidemic insurance costs deducted from proceeds	0.16%	0.08%	0.14%	0.02%	0.86%
Share of miscellaneous costs deducted from proceeds	0.38%	0.47%	0.20%	0.00%	4.15%
contribution margin	16.68%	7.27%	16.16%	-49.08%	40.51%

$$Modified\ Sharpe\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{mVaR}$$

Table 1 provides an overview of the performance measures described above. The performance measures can generally be subdivided according to their underlying distribution assumption, the risk measure and whether the measure can only be used in one market or in various markets.

5. Empirical estimates of the alternative performance measures in the context of pig production

In this section, we compute the above performance measures with data from pig fattening farms in Germany. The data was made available by 'Erzeugerring-Westfalen', a consulting organization which advises pig farmers in the federal state of North Rhine-Westphalia. 'Erzeugerring-Westfalen' collects on an annual basis technological and economic data from its member farms. The dataset comprises both data on farm structural features and data relating to the pig fattening enterprise. The latter include biological performance data, annual proceeds including inventory changes[9] and the costs directly attributable to the enterprise such as piglet costs, feed costs, epidemic insurance costs, dues and miscellaneous costs. The data set allows us to compute the share of gross margin in proceeds. Table 2 shows the descriptive statistics of the data set. It displays the proceeds, the shares of costs in proceeds and the share of gross margin in proceeds. It is clear from the table that piglets and feeds represent the two most important cost components in pig fattening, with 43.79% and 35.85%, respectively. Other direct costs play a minor role. On average, gross margin accounts for 16.68% of proceeds. The gross margin is available to cover fixed and overhead costs as well as the farmer's labour input.

'Erzeugerring-Westfalen' collects data from about 650 member farms. We used this data source to create a balanced panel of pig farms for the period 1999 through 2010. Balanced panel means that each farm is observed in each of the 12 years. This resulted in 159 farms being included in the analysis. Multiple years are required to compute the measures of volatility that enter the performance measures presented in section 4.

As explained in section 3.2, knowledge of the distribution of the returns is important for choosing the appropriate performance measure. For that reason, we carried out a test of fit on the returns data provided by 'Erzeugerring-Westfalen'. We used the Palisade @Risk software to identify which of the 22 given distribution types best fit the data. All three test statistics (Chi-Square, Anderson-Darling and Kolmogorov-Smirnov) identified a logistic distribution as the one with the best fit. Figure 2 shows a histogram of the empirical and fitted logistic distribution. It is clear from visual inspection that returns are not normally distributed.

The empirical distribution of $\overline{R_i}$ has a negative skewness of -1.18 and a kurtosis of 10.3, indicating a slight predominance of downside variance in pig production. The kurtosis reinforces the evidence that returns are not normally distributed. This in itself violates the (strict) preconditions of the Sharpe Ratio and supports application of one of the tailor-made

[9] In the following 'proceeds' is used equal to 'proceeds including evaluated changes in inventory'.

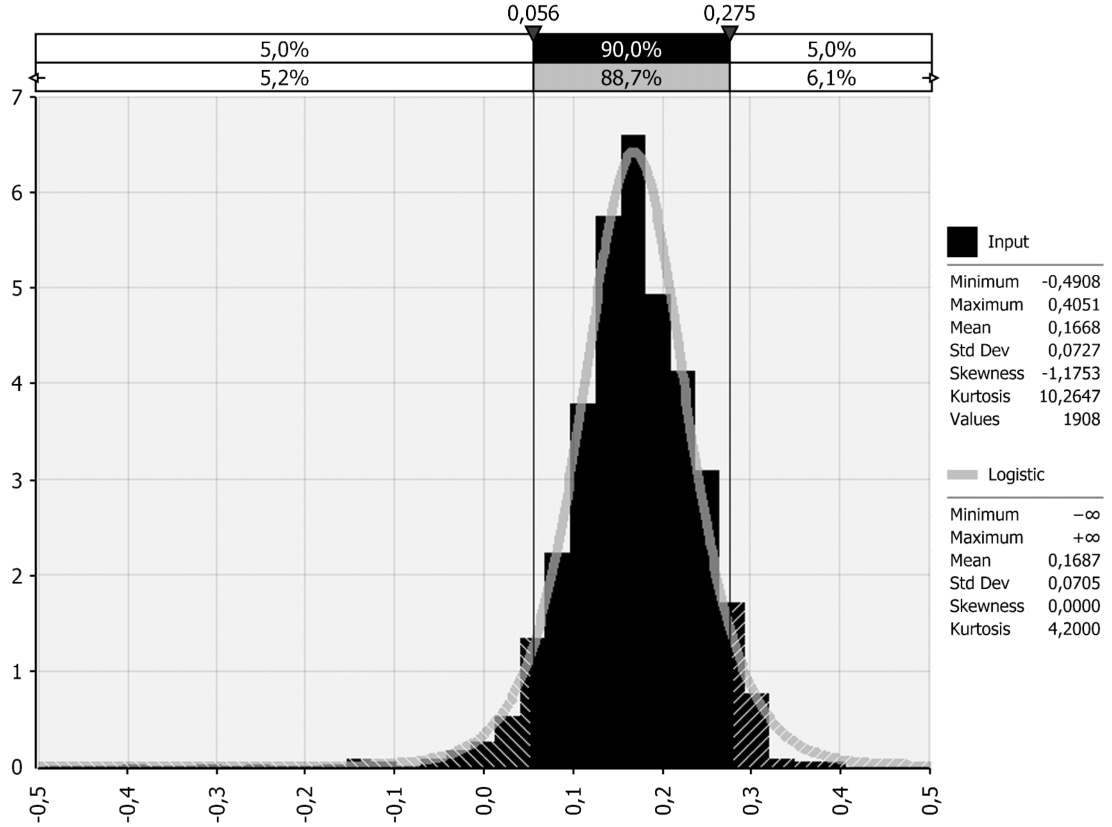

Figure 2: Distribution of returns $\overline{R_i}$ (N=1908, equivalent to 159 farms over 12 years)

performance measure such as the 'Modified Sharpe Ratio'.

Nevertheless we computed all performance measures presented in section 3 for each of the 159 farms. Table 3 shows the mean, standard deviation, minimum and maximum of the computed performance measures. The values of the Sharpe Ratio and the Sortino Ratio are consistently very close to each other. The Sortino Ratio, which is based on the Sharpe Ratio, thus seems to provide no fundamentally different results. The other performance measures cannot be compared directly with the Sharpe ratio by their absolute values.

For this purpose, we calculated the Spearman Rank Order Correlation Coefficients between the different performance measures (Table 4). The performance measures are highly correlated. All coefficients are >0.960. This shows that a ranking of the farms, regardless of the choice of the performance measure, would lead to (nearly) identical results.

To check the robustness of results, we carried out bootstrapping on over 10.000 samples of the empirical data. With the bootstrapping method, we randomly sampled our empirical dataset with replacement, in order to create a separate dataset. We finally computed the correlation coefficients for the new dataset. Bootstrapping is used inter alia to verify statistics based on small samples (Berger 2006). We produced 10.000 samples and determined a 95% confidence interval for the correlation coefficients. The correlation coefficients within the confidence interval between the different measures were always >0.94. The correlation coefficients calculated on the basis of our empirical data can thus be regarded as significant and robust.

Eling *et al.* (2007, 2010) also found, in their analysis of logistically distributed hedge funds returns, that – although the performance indicators have specific requirements concerning the distribution of returns – the different performance measures were very highly correlated. Pedersen *et al.* (2003) also estimated pairwise rank correlations of different performance measures for 400 financial services companies and also found a high correlation between the different measures.

The rank order correlation coefficients in Table 4 confirm the results of Eling *et al.* (2007) and Pedersen

Table 3: Descriptive statistics of the performance measures (N=159)

	Mean	Std. Deviation	Minimum	Maximum
Sharpe Ratio	0.0736	0.5579	-1.2219	1.7748
Sortino Ratio	0.0899	0.5883	-1.3809	1.6411
Treynor Ratio	0.0014	0.04	-0.2471	0.1097
Information Ratio	0.1707	0.9203	-1.7119	2.7848
RAP Measure	0.1678	0.026	0.1074	0.2471
Modified Sharpe Ratio	0.0235	0.1011	-0.2579	0.4691

Table 4: Spearman Rank Correlation Coefficient between performance measures

	Sharpe Ratio	Sortino Ratio	Treynor Ratio	Information Ratio	RAP Measure	Modified Sharpe Ratio
Sharpe Ratio	1.000					
Sortino Ratio	0.996	1.000				
Treynor Ratio	0.996	0.992	1.000			
Information Ratio	0.987	0.986	0.971	1.000		
RAP Measure	1.000	0.996	0.996	0.987	1.000	
Modified Sharpe Ratio	0.968	0.973	0.960	0.970	0.968	1.000

et al. (2003) in the context of hog fattening. The different performance measures are very highly correlated, implying that the ranking of farms would not be sensitive to the underlying performance measures. For this reason, non-normally distributed data does not seem to preempt application of traditional mean-variance based performance measures such as the Sharpe Ratio. In terms of an inter-company comparison, based on a ranking of the performance measures, no difference in the result can be expected, no matter which performance measure is used.

6. Relationship between risk and return in the data set

We now turn to the question of whether higher returns are always associated with higher risk. In an efficient market, increasing risk would always correlate with increasing returns – otherwise the farms can be separated into efficient and inefficient farms. A farm is considered efficient if no other farm exists that obtains higher returns with the same or a lower level of risk.

Figure 3 shows a scatterplot of the farms' mean returns and the variance of returns. It is clear from the figure that there are farms with different levels of risk at the same level of returns and vice versa. This graph illustrates that there are inefficient farms in our show case market of pig production.

We tested the mean returns $\overline{R_i}$ and the variance of returns R_i by a Chi-Square, Anderson-Darling and Kolmogorov-Smirnov test for a normal distribution. All tests rejected the normal distribution. For this reason, we also calculated the Spearman Rank Order Correlation Coefficient between the mean returns and the variance of the returns. The correlation coefficient of -0.0353 indicates no correlation between risk and returns and confirms the results of the graphical analysis in Figure 3. These results are clear evidence for the existence of inefficient farms in the market. An investor who intends to invest in this market would have to expect different levels of risk at the same level of returns, depending on the individual farm in which he invests. A rational investor would then always choose the highest return on investment. All other investments are inefficient.

7. Conclusions

In this paper, we have demonstrated the applicability of performance indicators used in the finance industry to the context of pig production. By aggregating risk and return into one figure, the indicators provide a more comprehensive basis for assessing farm performance than singular performance criteria. The risk-adjusted performance measures can be used for inter-company comparisons of pig farms or for assessing farms in the context of loan applications. Banks may be willing

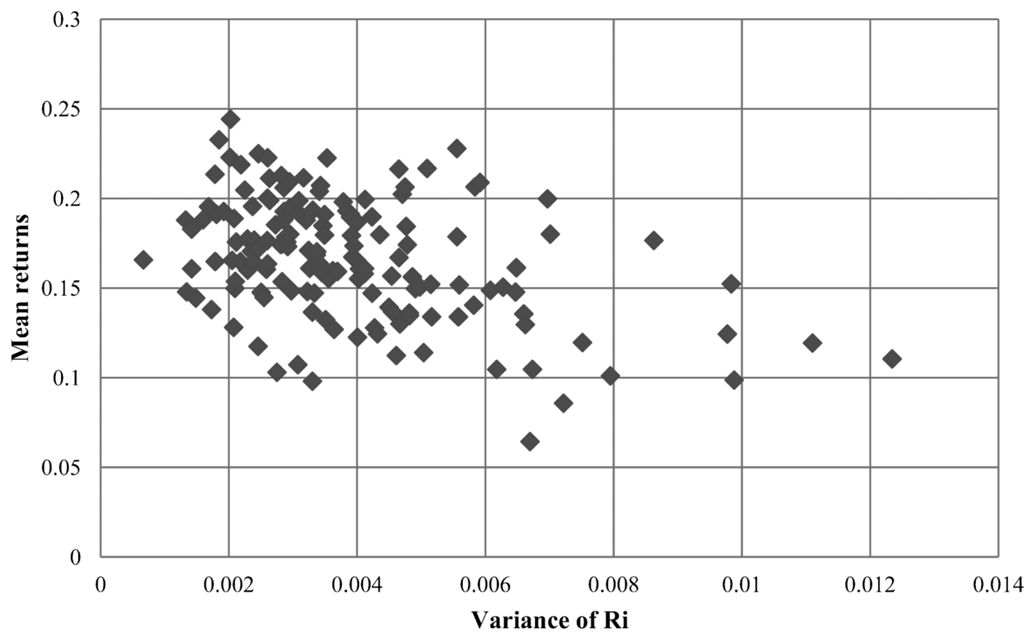

Figure 3: Scatterplot of returns and variance of returns (N=159)

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to offer farms with above-market performance more attractive loan conditions than farms performing below the market average. Likewise, farm consulting organizations may use highly performing farms as benchmarks for less well performing farms. Obviously, the advantages of using performance measures which explicitly cater for risk are greater the more volatile the markets are.

We have further demonstrated that, even if the condition of normally distributed returns is violated, there is no practical need for tailor-made performance measures which do not rely on the assumption of normally distributed returns. Such measures take higher moments of distribution into account in order to approximate the empirical distribution. The ranking of the farms in our data set – investigated with the use of Spearman Rank Order Correlation Coefficients – turned out not to be sensitive to the performance measure used. This finding confirms the results of Eling *et al.* (2007, 2010) who showed the same outcome for hedge funds returns. We can thus conclude that the scientific debate as to the need of tailor-made performance measures for non-normally distributed returns does not seem to be of great relevance for practical applications.

For practical purposes it seems more important that the performance indicator is intuitive and easily understood by the relevant stakeholders. Risk measures that represent the volatility of returns are of limited use, because they are not intuitively understood by the farmer. We rather recommend for practical application the beta factor. The beta factor represents the systematic risk of a particular farm and not – as most other risk measures do – the overall risk which may be seen as being too abstract in practical farm consulting. The message of the beta factor is straightforward:

- $\beta>1$: the risk of the particular farm is higher than the market risk
- $\beta<1$: the risk of the particular farm is lower than the market risk
- $\beta=1$: the risk of the particular farm is equal to the market risk

The same applies to returns. In all performance indicators, returns are measured as excess returns $\left(\overline{R_i}-\overline{R_m}\right)$. As with the beta factor, the farmer can also quickly recognize whether his or her returns are above or below that of the market:

- Positive excess return: the returns of the particular farm exceed market returns. The farm has ‘beaten’ the market.
- Negative excess return: the returns of the particular farm are below market returns. The farm has underperformed relative to the market.

These two relative indicators of risk and returns are combined in the Treynor Ratio. As stated above, the empirical analysis in this paper has revealed no major differences between the performance measures, so that we can focus on the comprehensibility of the performance indicator. The fact that the Treynor Ratio is based on relative figures with respect to both returns and risk seems to be a key advantage over alternative performance measures in terms of intelligibility.

The downside of the relative assessment of returns and risk is that the Treynor Ratio can only be used for comparisons within a market. For comparisons among different markets, e.g. pig fattening and breeding, absolute performance measures such as the Sharpe Ratio must be used. In that case, the excess return cannot be based on the returns of the respective market. Rather, some neutral third-party return, such as that of a government bond, is needed.

Finally we demonstrated the existence of inefficient farms in the pig fattening industry in that higher risk is not always associated with higher returns. This finding highlights the importance of the presented performance measures. Investments in the pig fattening industry should be consistently thought out and should, like all investments, be based on a comprehensive analysis including risk considerations. While the performance measures presented in this paper can reveal such inefficiencies, they provide no information as to the underlying causes. This aspect warrants further research.

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REFEREED ARTICLE

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Facilitating small grain production system innovation in the Western Cape, South Africa

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ABSTRACT

The profitability of current grain production practices is under pressure, while alternatives are limited due to the nature of the physical/biological environment of the Western Cape of South Africa. The search for ways to enhance the profitability of grain production systems requires the incorporation of expert knowledge and the stimulating of creative thinking, focused on generating ideas that could alter the whole-farm system. Expert knowledge may already exist, but could have become disunited due to disciplinary specialisation. Within multidisciplinary group discussions, knowledge is pooled, and due to the dynamics of group discussions, creative thinking is naturally stimulated. Whole-farm multi-period budget models – parameterised to quickly show the impacts of suggestions to the farm system – are used in group discussions, not only to save time by quickly identifying feasible suggestions, but also to stimulate creativity by immediately confronting experts with the financial implications of suggestions. This method of combining budget modelling and group discussions was used to generate area-specific alternatives that could improve whole-farm profitability in six different production areas in the Western Cape.

KEYWORDS: creative thinking; whole-farm systems; multidisciplinary group discussions; grain production

1. Introduction

Relatively low returns on investment and the volatility of commodity prices force grain producers in the Western Cape of South Africa to constantly seek improvements or alternatives to current farming practices. The low profitability of most agricultural commodities is caused mainly by a constant input-output price squeeze. The options available to producers to overcome this problem are limited due to physical and biological constraints, the typical fixity of assets in agriculture, and risks involved in switching to untested practices in a particular area. The producer is thus caught in the predicament of not being able to continue with current practices, yet ill-considered alterations to the farm system may do severe damage to the farm's financial position. Added to the issue of profitability is a constantly growing awareness among consumers of environmental responsibility, which adds an ecological dimension to the producer's goals (McCown *et al.* 2006).

The challenge to overcoming the pressure on whole-farm profitability lies in being able to identify physically and biologically feasible strategies aimed at increasing profitability, and then being able to examine their wider consequences within the farming system, ultimately, in financial terms. For instance, an alteration to a crop rotation system could have significant ripple effects on the whole farm.

Research in agriculture focus either on improving technology or on generating information (Pannell 1999). Fields such as agronomy, entomology, plant pathology, soil science and genetics are mainly concerned with technological improvement, while agricultural economics focuses on information (Byerlee and Tripp 1988). Research in farm management mainly focuses on generating knowledge that is adaptable and relevant in principle (McCown 2002), while the specific need of producers is for practical knowledge applicable to specific situations (McCown, Brennan *et al.* 2006). For management purposes, producers desire information on what the expected outcome of a decision or scenario would be. This requires of academics in farm management to provide a tool to define the expected outcome, and together with farmers, apply logic to reach a decision (Malcolm 1990; Pannell *et al.* 2000).

To generate possibilities for enhancing profitability of grain production systems requires the merging of expert knowledge. This paper aims to show the value of bringing a multidisciplinary group of experts face to face with a management model to generate valuable decision-making knowledge for researchers and producers. The challenge is to accurately capture and measure the knock-on effects caused by suggested changes to the farm system.

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2. Multidisciplinary group discussions

Before deregulation of agricultural marketing in 1996 the Wheat Board was particularly powerful under the policy of food self-sufficiency which contributed to a shift towards wheat production from other grain crops (National Agricultural Marketing Council (NAMC) 1999; Kleynhans *et al.* 2008). Continuous wheat production was subsequently adopted by producers in many areas of the Western Cape. After deregulation the relative importance of wheat to crops such as barley, oats and canola consequently decreased (Edwards and Leibrandt 1998). The following factors further contribute to the complex nature of the small grain farming system: the diversity of crops and livestock; the implementation of new technology; the role and contribution of livestock; the multiple interactions and interrelatedness among crops; various diseases, pest and weed problems; constantly changing product and input prices; awareness about sustainability; uncertainty about commodity markets; political issues regarding land reform and labour wages and the increasing uncertainty of weather patterns due to global warming. The farm system is thus characterised by complexity, consisting of a growing number of parts and relationships (Flood and Carson 1988; Checkland 1993). This complexity and continuous expansion of the external environment increasingly requires the incorporation of human interaction in management decision-making within a systems approach (Ison *et al.* 1996; Jackson 2006; Leleur 2008). The systems approach is well developed and documented, but is possibly underutilised in practice (Ackoff 1974; Severence 2001; Hammond 2003). A research method that accommodates and supports a systems approach is multidisciplinary group discussions. As a method or technique for generating information and knowledge, it started in the military during World War II and evolved to become widely used in operations management and farm management (Linstone and Turoff 1975; Whyte 1989; Doll and Francis 1992; Fildes and Ranyard 1997; Calheiros *et al.* 2000; Colin and Crawford 2000; Van Eeden 2000; Haggar *et al.* 2001; Jabbar *et al.* 2001; Hoffmann and Laubscher 2002). Farm management research, which by definition is multifaceted, relies on the use of a pool of knowledge from various disciplines (Hoffmann and Laubscher 2002; Bullock *et al.* 2007).

The focus of scientific research, led to specialisation and the development of scientific disciplines (Johan Mouton, *pers. comm.*, 2009). Discipline-based research often reinforces the fragmentation of knowledge which may already exist and counter solutions to real-world problems (Malcolm 1990; Janssen and Goldsworthy 1996). An example of such research is technical research that ignores the financial implications of proposals on whole-farm profitability or economic research that disregards the technical and physical-biological considerations regarding the implementation of suggested strategies. Financial-economic research is usually of a diagnostic nature, and is usually based on time series or cross-section data to identify reasons for failure, rather than generating new ideas to lessen the price-cost squeeze. Consequently, multidisciplinary research methods are used to accommodate participation across disciplinary gaps (Young 1995; Moore *et al.* 2007). Examples of scientific disciplines related to grain production include agricultural economics, resource economics, agronomy, soil science, plant pathology, entomology, labour management and animal science.

The challenge for researchers, studying the whole-farm system lies in facilitating multidisciplinary participation (Röling and Wagemakers 1998; Keating and McCown 2001; McCown 2001; Bosch *et al.* 2007). This requires integrating natural science, social science and indigenous knowledge (Young 1995; McGregor *et al.* 2001; Jeffrey 2003; Francios 2006; Vandermeulen and Van Huylenbroeck 2008). Another reason for using multidisciplinary expert group discussions is the exploratory nature of the research, which in this case is aimed at identifying ways of improving whole-farm profitability. The implication is that some of the required information does not exist at present. Experts can base their judgement of the impact of changes to the farm system on experience and knowledge. Compared to other methods, expert group discussions are more time efficient in generating information.

The most important contribution of group discussions is that it stimulates creative thinking in groups. The height of creativity is the creative shift, which happens when an individual are made aware of alternative perspectives. Creative thinking can lead to either inventive thinking, the provision of new ways of solving existing problems, or innovative thinking, the modification of approaches, based on a thorough understanding of principles (Hare 1983; Linstone 1984). As this happens naturally in group discussions it creates an ideal situation for creative thinking (Leleur 2008) and often leads to new ideas (Krueger 1994; Litosseliti 2003; Porac *et al.* 2004). When new ideas are generated, other group members can help verbalise these new ideas. Coupled with the aforementioned processes, the resources that individual members (which include knowledge, experience and insight) contribute to the group are equally important regarding the ability of group discussions to generate new ideas (Thompson and Choi 2006). This increases the importance of the correct selection of participants for group discussions.

The expert groups comprised of participants from various scientific disciplines as well as producers and extension officers from local agribusinesses. The participating scientists were selected by identifying the foremost-recognised researcher within a specific field within the Western Cape. The producers were selected based on active participation in producer study groups, industry information days, competitions and research. The chairperson's role was focusing the discussions on the relevant issues. Scientist's quantified the technical impacts, input/output relationships and sustainability impacts of suggestions on the broader system. Agricultural extension officers, from local agribusinesses, are well exposed to industry-level issues, have thorough knowledge of the area and experience of a broad variety of farm situations. The extension officers can identify critical issues; describe limitations to suggested strategies from an industry level, and describe and identify the homogeneous areas and typical farms. The strength of the producers is their practical knowledge of the farm system and relating practical implications of suggested strategies made by other participants. The main contribution of the agricultural economists was their quantification of suggested improvements to the farm system in financial terms. Suggestions made by other participants had to be expressed in financial terms for the farm models to calculate the expected effect on profitability.

3. Quantifying outcomes of group discussions through financial modelling

It is important for farmers, researchers, extension officers and policy makers to understand the financial impact of technical changes to the farm system. Physical simulation of a farm is not practical, and most farm-specific case studies are not representative; therefore, computerised whole-farm models are used to assess the complex issues involved in farming, and their impact on farming. Models themselves do not generate new information; they only facilitate the processing of information. The multifaceted nature of the whole farm necessitates the use of multidisciplinary teams to accommodate the variety of expertise necessary for accurate assessment of whole-farm issues. In multidisciplinary discussion groups, models can serve as tools to stimulate discussions and generate new discussion points by financial evaluation of possible outcomes. Modelling is typically used in studies that aim at developing and validating accurate representations of the real world, allowing research questions of a descriptive, causal and predictive nature to be addressed (Brenner & Werker 2007:229; 2008; Steward 1993:13 and White 1971:294).

The development of modelling was founded on two factors. The first factor was the social notion that the natural world could not only be scientifically explained, but also scientifically managed. The second factor was the technological advancement and development of the computer, which also allows for exploring hypothetical systems (McCown 2002). Models can quantitatively compare alternative management options in terms of established criteria and known risks and be applied to design improvements on existing systems (Robson 1994; Attonaty *et al.* 1999).

In agriculture, computer models are widely used as planning and exploration tools in fields such as agricultural economics, farm management, crop management and livestock production (Glen 1987). The justification for models as research tools in agricultural systems is their practical use. The key to useful models is their relative simplicity, which can be achieved by setting well-defined objectives. The pre-occupation of systems researchers with simulation and model building, with less attention paid to applications, may lead to either limited practical use or suspicion among producers who do not understand the functioning of the model (Doyle 1990).

During group discussions, 'live' simulations of the whole farm were used to quickly assess the financial implications of suggestions made by participants. This serves two purposes. The first lies to quickly identify suggestions that contribute positively to profitability. These suggestions can then be further discussed and refined, while suggestions with a negative effect on profitability can be discarded. Secondly the model plays the role of one of the experts and contributes an alternative, financially quantified perspective, which contributes to the stimulation of creativity during group discussions. Participants are immediately confronted by the financial implications of their suggestions (Snabe and Gröfsler 2006).

To generate information on the typical farm in financial terms and accurately simulate the expected impacts of suggested changes, the quantitative method needs to meet a number of requirements.

- Its ability to accommodate and capture complexity and accurately reflect the nature of the system being modelled (Marks 2007). Accommodating complexity requires, *inter alia*, the ability to measure the sensitivity of certain performance criteria to variations in a range of variables, including structural variations. Performance criteria include standard profitability indicators such as IRR and NPV measured over a twenty year period. A change in, for example, input levels will instantly reflect as a relative change in profitability. The ability to cope with complexity is embedded in a detailed quantification of the factors and interrelationships that comprise the farm system.
- Producers and natural scientists will mostly contribute information of a physical-biological nature. Hence, the method needs to translate such inputs into financial data and inputs.
- The most important requirement of the method is adaptability. The key to identifying viable strategies that could improve farm-level profitability is the creativity produced by group discussions. To enhance creative thinking, the financial impact of suggestions on the whole farm should be presented immediately to indicate whether the proposed plans are financially viable and justify further exploration.
- The model's user-friendliness allows for its utilisation and the interpretation of its results by stakeholders who are not necessarily from a financial or managerial background. User-friendliness can overcome the threat of expert group discussions being reduced to a diagnosis of the method, and focus on developing innovative ways of improving the problem (Janssen and Goldsworthy 1996).
- The method further needs to accommodate multi-period, whole-farm financial evaluation. The importance of this requirement is embedded in the systemic nature of the whole farm and its specific cropping systems. The selected method needs to accommodate and accurately calculate long-term implications, such as the producer's goals, the replacement of machinery and livestock, and the benefits of crop rotation systems, in a valid way.

Accounting models use farm-level budgets (partial budgets, enterprise budgets, whole-farm budgets and cash-flow budgets) to assess farm-level activities, usually based on some profitability indicator. Budgeting is perhaps the most widely used method of financial planning that evaluates plans in physical and financial terms. The popularity of budgets stems from their simplicity of use and the fact that they aid in the heuristic approach to decision-making, rather than imposing an analytical framework on the decision maker (Rehman and Dorward 1984). Budgets are often used as comparable quantitative techniques and play an important role in benchmarking (Malcolm 1990). The development of computer technology introduced a dimension to budgeting methods that allowed budgets to be used as dynamic planning and decision-making tools. In this sense, budgets can now be classified as simulation models that are based on accounting principles and methods, rather than purely on mathematics (Pannell 1996). Whole-farm budget models are normally developed using spread sheet programmes which allows for the expression of complex and sophisticated calculations and relationships in a relatively simple way. The sophistication of budget models lies in their ability to allow for detail, adaptability and user-friendliness (Keating and McCown 2001).

Whole-farm budgets are drawn up to show anticipated consequences, in terms of selected criteria, proposed farm plans, parameters and policy options. These incorporate physical as well as financial parameters and usually produce profitability criteria such as net farm income or cash flow (Dillon and Hardaker 1984). Some of the other quantitative techniques focus on optimising the whole-farm gross margin. Whole-farm budgeting, however, quantifies and subtracts overhead and fixed costs to return a net farm income value. Net farm income is commonly used for a financial comparison of farming units. With some adaptation, whole-farm models may also be extended over time to calculate returns on capital invested and profitability indicators such as the internal rate of return on capital investment (IRR) or net present value (NPV).The limitations of budget models are similar to those of simulation models, the most important criticism being the lack of an optimisation goal, or the possibility of them not returning a 'best' solution.

The important contributing factor in identifying and developing strategies to improve profitability and sustainability is creativity. The process thus lean on creativity generated within the group discussions and the budget models thus serve a supporting role. Suggestions can quickly be evaluated in terms of financial impact within the group discussion. This not only focuses the discussion on strategies with a positive impact, but also adds another perspective, which in turn further stimulates creativity.

4. Strategy identification and development for relatively homogeneous areas and typical farms

The variation in climate, terrain and soil necessitated that the production area of the Western Cape be divided into smaller, more homogeneous areas. Expert groups were used to validate the homogeneous areas suggested by various experts. Relatively homogeneous production areas were used to distinguish the areas, as well as characteristics such as farming practices, typical crop rotation systems, typical machine replacement policies and affiliations to agribusinesses. The Western Cape, in terms of grain production, can be divided into the Swartland and the Southern Cape region. The areas were specified by consulting the literature and visiting various experts before the group discussions took place (ARC Small Grains Institute 2003; Barnard 2007; Haasbroek 2007; Parkendorf 2007; Wallace 2007). In principle, it was decided to decrease the size of the homogeneous areas to allow for higher homogeneity, especially in the Southern Cape. Relatively homogenous areas are usually defined in terms of soil, terrain and climate. In this instance typical farm sizes, cropping systems and cultivation practices were also considered. In the Swartland, the three areas are Koeberg/Wellington (500-750 mm/annum rainfall), the Middle Swartland (350-600 mm/annum rainfall) and the Rooi Karoo (250 -400 mm/annum rainfall). The three areas in the Southern Cape are the Goue Rûens (500–700 mm/annum rainfall), the Middle Rûens (300-500 mm/annum rainfall) and the Heidelberg Vlakte (300-500 mm/annum rainfall). The Swartland and Southern Cape regions are shown on a map in Figures 1 and 2 which illustrate the relatively homogenous farming areas.

The correlation between rainfall and grain yields in the Western Cape is 85% (Barnard 2007; Parkendorf 2007). From a climatology point of view, the factors that influence rainfall in the winter rainfall areas include global weather patterns, upper-level atmospheric circulation, oceanic variability and sea temperature. The characteristics of the land that also impact on rainfall include height above sea level, the distance from the coastline, and natural barriers like mountain ranges (Valero *et al.* 2004; Xoplaki *et al.* 2004). The result is extremely high inter-annual variability of precipitation, making it impossible to detect long-term trends and patterns accurately. If trends cannot be identified, predicting the future occurrence of wet and dry seasons is highly risky. Total rainfall for the season is not as important as the dispersion of precipitation during the growing season. Various examples were presented during the workshop discussions of relatively low yields obtained per hectare, despite relatively high total seasonal rainfall, due to high concentration in specific months (and vice versa.) The 2003 season is an example where relatively low total rainfall, but during the critical stages of plant growth, led to relatively high yields.

The workgroup agreed that a trend in the sequence of wet and dry years could not be predicted, which is in accordance with the literature. However, a distinction in terms of rainfall and rainfall dispersion can be made among good, average and poor years. The budget model runs over a twenty-year calculation period, which means that the number of good, average and poor years will have an impact on the profitability of the farm, especially the expected cash flow. The definition for each is as follows:

- A good year is when the rain falls at exactly the right times in relation to the water requirements of the crops. This means sufficient rain for planting, with good follow-up rain that increases throughout the growing season and peaks during seed filling, and then decreases towards harvesting time.
- An average year would mean sufficient total rainfall for the year. It deviates from a good year in that rainfall may be late for planting, or falls mostly during planting and then levels off towards seed filling, or there may be too much rain towards harvesting time.
- A poor year would entail receiving sufficient rain, but too late for planting, followed by a decrease in rainfall through the crucial growing phases, or a

Figure 1: Homogeneous areas for the Swartland
(Course of M. Wallace, GIS manager, Western Cape Department of Agricultuer, Elsenburg)

concentration of rainfall during harvest. A poor year can also be caused by a drought.

The workgroup allocated typical yields for each crop according to the above-mentioned definitions. Table 1 shows expected yields for good, average and poor years along with their frequencies for wheat, barley and canola for each homogeneous area. The prevalence of good, average and poor years out of ten years for each region gives a good indication of the risks involved in crop production.

For each homogeneous area, a typical farm model was developed. The extents of the typical farms (farm size, land value, yields, mechanisation infrastructure and overhead cost) were validated during the group discussions. A typical farm was not developed to establish relevant information on individual farms, but rather to develop a model to which alternatives could be compared (Fuez and Skold 1991). Profitability of the typical farm is calculated over a 20-year period. A whole-farm multi-period budget model was used for calculating the IRR for each farm. To establish the current financial position of each farm, the range of factors that the farm system entails and the relationships between such factors needed to be captured. The factors

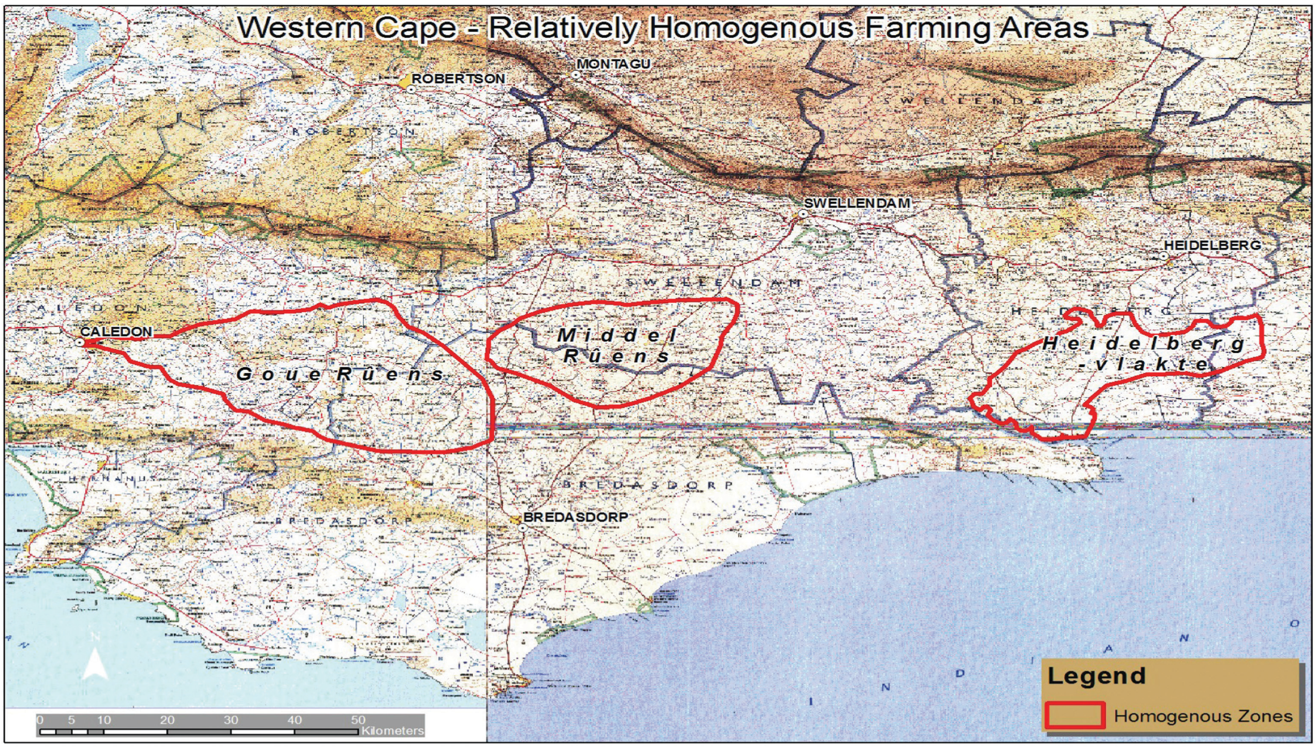

Figure 2: relative homogeneous areas for the Southern Cape
(Course of M. Wallace, GIS manager, Western Cape Department of Agricultuer, Elsenburg)

and interrelationships that influence and determine profitability were incorporated in such a way that these factors could be manipulated and could instantly show the financial impact on the entire farm. The variables are presented in data tables outside of the model, changes are made to such variables and run directly into

Table 1: Expected yields (and grazing capacity) and associated prevalence of good, average and poor yield years for wheat, barley and canola

Area/Year	**Wheat**		**Barley**		**Canola**		**Grazing capacity**
	Yield (t/ha)	In 10 Years	Yield (t/ha)	In 10 years	Yield (t/ha)	In 10 years	Ewes/ha pasture
Swartland:							
Koeberg/Wellington							2.5
Good	4.1	3	-	-	2.0	3	
Average	3.5	6	-	-	1.5	5	
Poor	2.5	1	-	-	1.0	2	
Middle Swartland							2.1
Good	3.0	2	-	-	1.8	2	
Average	2.4	7	-	-	1.4	6	
Poor	1.8	1	-	-	0.8	2	
Rooi Karoo							2.0
Good	2.0	1	-	-	1.5	1	
Average	1.5	5	-	-	1.0	4	
Poor	0.7	4	-	-	0.5	5	
Southern Cape							
Goue Rûens							2.8
Good	3.5	4	3.3	4	1.6	3	
Average	2.9	5	2.7	5	1.3	3	
Poor	2.3	1	2.1	1	1.0	4	
Middle Rûens							3.0
Good	2.5	3	2.5	3	1.5	3	
Average	2.2	5	2.2	5	1.2	3	
Poor	1.8	2	1.8	2	0.8	4	
Heidelberg Vlakte							2.0
Good	2.4	2	2.4	2	1.4	2	
Average	2.0	4	1.8	4	1.1	4	
Poor	1.5	4	1.5	4	0.8	4	

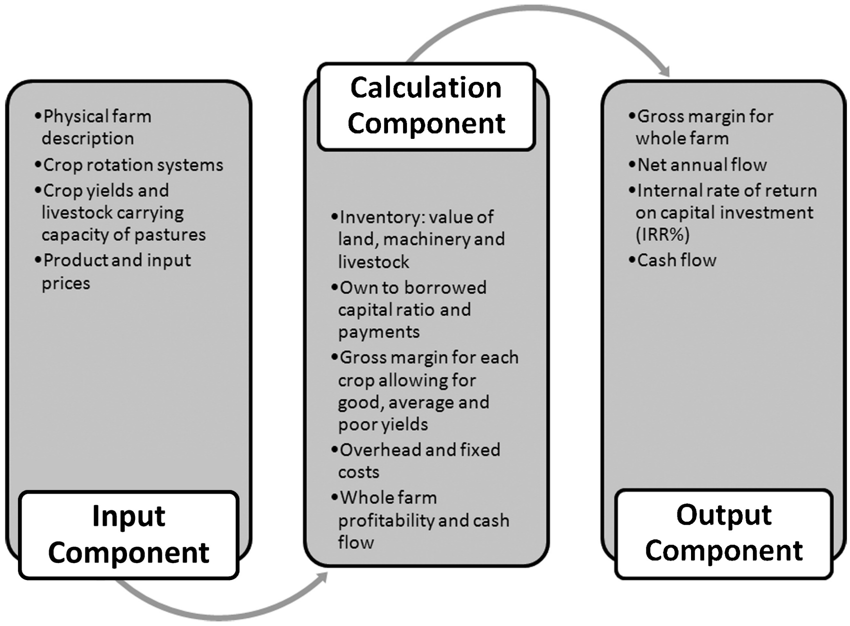

Figure 3: A graphic representation of the components of the whole-farm, multi-period budget model

the model. The whole-farm, multi-period budget models that were developed for each area consist of various sets of data and calculations that are interconnected and based on standard accounting principles and methods. These include price tables for inputs and products, input levels, yield levels, crop rotation systems and sequence of crops, running costs for machinery sets and labour use. The components of the budget model are shown in Figure 3. It illustrates the input component, calculation component and output component of the budget model. Each component consists of various interrelated parts that ultimately impacts on the calculation of whole farm profitability, measured in IRR and NPV.

Adaptations in terms of farm size, crop rotation system, input costs, interrelationships, investment, replacement of machinery, price levels and own versus borrowed capital can be accommodated in a spread sheet budget model. For the typical farm, all the factors forming part of the 'input component' as well as some of the factors of the 'calculation component' were determined from various interviews and information received from study groups, and validated during the group discussions.

Table 2 shows the expected NPV and IRR for the typical farm for each relatively homogeneous area. The areas with an IRR lower than the real interest rate of 4.69% all return a negative projected NPV for the 20-year calculation period. Despite the higher land prices and consequent higher investment requirement, the high-yield areas show the highest projected profitability. The Middle Rûens is expected to be worst off in terms of long-term profitability.

One of the goals was to identify ways to improve the profitability of grain production in the Western Cape. To achieve this, the expert groups were challenged during the group discussions with identifying the optimum means of doing so. The model was used as a tool to measure and immediately show the expected financial effect of proposals on the whole farm. The experts also validated the technical feasibility of the suggestions. For instance they can point out the feasibility of a change in crop sequence in relation to impact on soil fertility, breaking of weed or pest cycles and mechanisation requirements.

In all instances, the systems nature of the farm enterprise dictates that all changes in parameters, assumptions, relationships and costs will impact on other parts of the system. A change in any factor that will influence the cultivated area for each crop will affect other parts of the system. The model is sensitive enough to show the relative impact of changes to cultivated area to other factors, such as investment requirement. These factors are, for instance, the mechanisation requirements, the size and structure of the livestock component, the farm's gross margin, overhead costs, and profitability. Changes in crop rotation system, brought

Table 2: The net present value (NPV) and internal rate of return on capital investment (IRR) for each typical farm

Area	Net present value (NPV) Rand (R)[1]	Internal rate of return (IRR) (%)
Koeberg/Wellington	2,681,251	5.67
Middle Swartland	-692,903	4.20
Rooi Karoo	-1,312,288	3.05
Goue Rûens	3,008,647	5.63
Middle Rûens	-4,862,538	1.05
Heidelberg Vlakte	-2,385,022	3.21

[1]In mid-December 2013, R10 was approximately equivalent to £0.59, US$0.96 and €0.70 (www.xe.com).

Table 3: Impact of proposed strategies on the profitability of the typical farms for the Swartland area

Area	Strategy/Scenario	Profitability (IRR%)
Koeberg/Wellington	Status quo	5.67%
	An extra wheat cultivation in the rotation system	5.89%
	Longer replacement interval for machinery and equipment (20 years for harvesters and 15 years for tractors, instead of 12 years)	7.00%
	Increased livestock stocking rate (2.8 instead of 2.5 ewes per ha of pasture)	6.00%
	Permanently replace one wheat crop in each system with oats as pasture	5.55%
Middle Swartland	Status quo	4.20%
	Shift to 60% of area utilised for wheat-medics rotation system	5.46%
	Longer life expectancy for machinery, and cheaper machinery	5.35%
	Higher livestock stocking rate (2.5 ewes per ha instead of 2.2) and less use of nitrogen fertiliser as top fertiliser (20kg/ha instead of 30kg/ha)	4.93%
	Permanently use one wheat crop in the medic-wheat rotation system for producing feed	4.01%
Rooi Karoo	Status quo	3.05%
	5% higher wheat yield in good and average years due to enhanced cultivation practices	3.54%
	Longer life expectancy for machinery, and cheaper machinery due to less intensive utilisation of technology	5.05%

about by, for example, the availability of new canola varieties, will influence the profitability of other crops in the system, the livestock component, the investment requirement for machinery, and overhead costs. Changes to the livestock enterprise, such as intensification, have a specific impact on the management of pasture, the use of stubble, the costs involved in making silage, and labour requirements. Cultivation practices impact on crop yields, mechanisation requirements and overhead costs, such as labour. For example a change in yield impact in a sequence the gross production value for wheat in a specific rotation system, the gross margin for wheat the gross margin for the total farm, profitability and cash flow, but also related costs such as marketing costs, transport costs and harvesting costs. The model quickly calculates the financial implications of any of the above-mentioned changes. The strategies for each area that are described in Tables 3 and 4 were all identified and discussed by the expert group and then fed into the model to assess their financial implications.

In the Swartland area, the severe summer droughts limit the options regarding pastures and crops such as barley. During the group discussions, it was established that more management effort could be invested in the livestock component, as it is currently focused mainly on wheat production. The planting and harvesting season in this area is also relatively short; therefore, effort went into the management of machinery and equipment, to extend the working life thereof. For both regions the focus fell mostly on optimising

Table 4: Impact of proposed strategies on the profitability of the typical farms for the Southern Cape region

Area	Strategy/Scenario	Profitability (IRR%)
Goue Rûens	Status quo	5.63%
	Downscaling on mechanisation and increasing pasture utilisation	5.72%
	Implementing a continuous cash cropping system on 20% of the cultivatable area of the farm	5.75%
	Increasing grain yields by 5% for good and average years, due to technological improvements	6.31%
	Effect of a 5% discount on the price of fertilisers and chemicals	5.96%
	All harvesting done by contractors	5.41%
Middle Rûens	Status quo	1.05%
	5% higher yield for grain crops in good and average years due to enhanced cultivation practices	1.64%
	Longer life expectancy for machinery and cheaper machinery due to utilisation of less sophisticated technology	2.99%
	Increased stocking rate for livestock (3.5 ewes per ha of pasture instead of 3.0).	3.13%
	Hire manager and increase stocking rate and crop yields.	0.97%
Heidelberg Vlakte	Status quo	3.21%
	6% higher yield for grain crops in good and average years due to enhanced cultivation practices	5.88%
	Using oats as pasture for livestock	3.69%
	Increased stocking rate for livestock (3.0 ewes per ha pasture instead of 2.0). Due to utilisation of oats as silage for livestock	5.09%

mechanization and the livestock component. Both these strategies showed significant improvements on expected profitability, however the way of implementation differ between areas.

5. Conclusions

To address the problem of the poor financial performance of grain farms necessitates that the research method meets two requirements. The first requirement is creativity, to identify ways to improve profitability in a sustainable manner. The second requirement is to calculate the financial impact of the proposed innovation on the whole-farm operation. This implies that the wider effects on interdependent components of the farm system must be captured. The calculation tool, in this case a farm model, must therefore effectively deal with the multi-faceted nature of the farm system, which consists of, and is influenced by a variety of interrelated physical-biological and socio-economic factors. The expert group made suggestions and, through dialogue and interaction with other experts, discussed and established the wider implications of such suggestions on the physical and biological characteristics of the typical farm. The budget model was used exclusively to determine whether suggestions made by the expert group would have a positive or negative impact on the profitability of the typical farm. The multidisciplinary, multi-perspective expert group discussions in combination with the use of budget models that immediately show the financial implications of suggestions made by the experts were successfully employed to identify and evaluate sustainable ways to increase farm profitability in each of the homogeneous areas. In various instances the models directed the discussions toward options that were financially more viable. In most instances, suggestions revolved around the mechanisation infrastructure and the utilisation of the livestock component.

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Energy cane usage for cellulosic ethanol: estimation of feedstock costs and comparison to corn ethanol

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ABSTRACT

To reach the US 2022 mandate of 136.3 billion litres of annual biofuel production, multiple sources must be integrated into the renewable biofuels supply chain. Energy cane appears well suited to help meet this mandate, particularly in Louisiana. Although not traditionally grown, production similarities to sugarcane make it an attractive option for Louisiana farmers if they are offered the 'right price.' If farmers are to switch hectares from sugarcane to energy cane, cellulosic ethanol processors must provide farmers an additional \$2.84/MT[5] and \$3.41/MT on a third and fourth stubbling above breakeven to make the net revenue on a per tonne basis from energy cane equal to that of sugarcane.

Providing farmers with the right monetary incentive is only part of the equation for ethanol processors, as they also need to determine if cellulosic ethanol from energy cane is competitive with corn ethanol. A breakeven analysis is utilized to determine the monetary incentive needed to cover the cost of production. An additional equation is used to evaluate the cost of cellulosic ethanol so that comparisons may be drawn between cellulosic costs and traditional corn ethanol costs. Our results indicate that this occurs at enzyme prices of \$0.04/l (projected enzyme costs), irrespective of energy cane yields, stubbling length, and/or corn prices. Since 2007, enzyme costs for the lignocellulosic ethanol process have fallen by \$0.07/l, which have increased the competitiveness of cellulosic ethanol relative to corn ethanol.

KEYWORDS: Biofuels; Production Incentives; Cellulosic Ethanol; Breakeven Analysis

1. Introduction

The use of ethanol as an alternative energy source has received significant publicity in recent years because of increasing oil prices and worries about future oil supply shortages. Moreover, US energy policies have also influenced the expansion of the ethanol industry; these policies include the banning of Methyl Tertiary Butyl Ether (MTBE), the 2005 Energy Policy Act, and the 2007 Energy Independence and Security Act (EISA). The phasing out of MTBE in 2000 created an opportunity for ethanol to become the primary oxygenate used in the production of gasoline (Energy Information Association, 2005). The 2005 Energy Policy Act established a Renewable Fuel Standard (RFS), which mandated 15.1 billion litres of biofuels be produced annually by 2006 and 28.4 billion litres annually by 2012 (Tyner, 2007). Since both of these mandated levels were surpassed before their deadline, a new RFS was passed in 2007 with a ratification of the 2007 EISA. This ratification mandated that fuel producers use at least 136.3 billion litres of biofuels by 2022. In addition, it placed an emphasis on the production of cellulosic ethanol (Office of the Press Secretary, 2007). The combination of these factors and others influence whether cellulosic ethanol becomes a significant contributor in the US energy market.

If this does occur, how does production agriculture respond? In 2009, 335.8 million tonnes (metric tons) of corn were produced on 32.2 million agricultural hectares in the US (USDA, 2011). If all of this corn were converted into ethanol, it would produce enough fuel to last approximately 64 days, based upon average US daily gasoline consumption (Energy Information Association, 2007).[6] Moreover, if corn were the only source of ethanol available for meeting the 2022 136.3 billion litre biofuel mandate, the US would have to allocate approximately 98% of its corn production to biofuels. Usage of corn at this level for ethanol is not sustainable given other demands for corn (i.e. feed grain in the livestock industry and consumer food products). The development of a cellulosic ethanol industry depends on usage crops that have less impact on the food supply (Coyle, 2010). Consequently, alternative

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[5] In mid-December 2013, US\$1 was approximately equivalent to £0.61 and €0.73 (www.xe.com).

[6] A conversion ratio of 11 liters of ethanol per 25.4 kg is assumed (Schnitkey *et al*., 2007).

crop sources will have to be utilized to meet this ethanol mandate.

Each geographic/production area within the US should produce the energy crop for which it has a comparative advantage. For example, in the Midwest, corn will probably continue to be the crop of choice, while for the Southern US, other biomass crops may be a more suitable energy crop choice. Energy cane could be that crop in Florida, Louisiana, and Texas. While energy cane and sugarcane are the same genus, *saccharum*, energy cane is bred for its high fibre and low sugar content, while sugarcane is bred for the opposite characteristics.

Unlike corn, ethanol from energy cane comes from two sources: 1) the sugar from the energy can be converted to ethanol and 2) the cellulosic material (fibre) from the energy cane can be processed into ethanol. Cellulosic technology is still in the developmental phase, and only a handful of companies (e.g. Abengoa, POET LLC, Koir's, and Fiberight LLC) are currently experimenting with producing ethanol from cellulosic materials (e.g. forestry by-products, wheat, corn stover and perennial grasses such as switchgrass and energy cane). The reason for the emphasis on cellulosic material is that the Renewable Fuels Association (2008) estimates that the 1.2 billion tonnes of sustainable cellulosic material available in the US on an annual basis could produce an estimated 227.1 billion litres of ethanol each year. Additionally, the majority of this biomass would be harvested from second-generation feedstocks (e.g. perennial grasses and forestry by-products), which are not used for human consumption (Biomass Research and Development, 2008).

Limitations and risks still exist with the usage of these second-generation feedstocks. For example, corn stover a potential biomass feedstock in the Midwest is constrained by both soil moisture availability and water/wind erosion (Kadem and McMillan 2003; Graham *et al.*, 2007). Additional limitations exist with the adoption of feedstocks such as energy cane and miscanthus, as well as other feedstocks. The markets for these crops are thin and secondary market options for these crops are just being developed. Jorgensen (2011), Bocqueho and Jacquet (2010) and Stone *et al.* (2010) discuss the risks associated with the production of various biomass crops. They note that with biomass feedstocks such as miscanthus there is an increased water need, susceptibility to diseases, and liquidity constraints that can arise from a producer switching to biomass production. Liquidity is a major concern for producers growing perennial crops, such as energy cane, as these crops have both significant upfront establishment costs and typically do not realize revenues in the first year of production (Ericsson *et al.*, 2009)

Given the limitations and risks associated with the production of biomass feedstocks, it is important to investigate all aspects of biomass production. The production of non-traditional crops such as energy cane creates a situation wherein producers are uncertain about whether and how these new crops will allow them to maintain future farm income at current levels. According to Beierlein *et al.* (1995), breakeven analysis can be used effectively as a 'first screening procedure' or 'ballpark technique' for a top-level examination. Khanna *et al.* (2008) employ a Net Present Value (NPV) framework to determine the breakeven price required to cover the cost of production for both switchgrass (10-year time horizon) and miscanthus (20-year time horizon). Hallam *et al.* (2001) also use a breakeven analysis to determine the required price needed to cover the total production costs for reed, canarygrass, switchgrass, big bluestem, alfalfa, sweet sorghum, forage sorghum, and maize. However, no such analysis exists for energy cane.

Consequently, this paper has two objectives: 1) to determine the breakeven price producers must receive to cover energy cane's cost of production and 2) to determine how increasing energy cane yield (mt/ha) and the price of corn impacts cellulosic ethanol's competitiveness with traditional corn ethanol. Energy cane production costs are significantly influenced by the cost of seed cane, which is the initial plant material that is purchased to start the energy cane crop. One of the key costs that influence the competitiveness of cellulosic ethanol with traditional ethanol is enzyme costs. In the last decade, enzyme costs have dropped by 80 percent (Advanced Ethanol Council, 2013). Taken together, these objectives will help better define the current economic feasibility of the production of energy cane.

2. Method

For the energy cane industry to take current production hectares away from sugarcane in Louisiana, energy cane production must generate expected net returns per hectare that are at least equal to the net returns for sugarcane. One way to evaluate this is through a comparison of expected net returns per hectare for the two crops. Given the lack of data on energy cane production, we examine breakeven prices for a variety of yields and two of the most common stubbling lengths. For a producer, these two variables are key drivers in crop choice decision. As the tonnes of energy cane harvested per hectare increases, the breakeven price required by the producer to grow energy cane declines. With respect to length of stubbling, the breakeven price required to cover production costs decreases as stubbling length increases. This occurs because fixed planting costs are spread across more years of production and a smaller percentage of the producer's land is devoted to energy cane seed production.

Comparison between Characteristics of Energy Cane and Sugarcane

Louisiana is the largest producer of sugarcane in the U. S. with approximately 172,000 hectares (425,000 acres) in 2009 (USDA, 2011), which means it has an established sugarcane production, harvest, transportation, and processing infrastructure. In addition, energy cane and sugarcane are also similar in how they are grown, where they are grown, and in their growing cycles. These characteristics, especially from a producer's standpoint, make energy cane a good candidate and viable alternative crop for farmers already producing sugarcane. In addition, energy cane's ability to produce substantial amounts of biomass per hectare and to grow under marginal conditions are reasons why this feedstock is an excellent candidate for cellulosic ethanol in Louisiana (Alexander, 1985).

Table 1: Brix and fibre comparison of a standard sugarcane variety and two energy cane varieties

Variety	Gross Cane (MT/ha)	Brix (% Cane)	Fiber (% Cane)
LCP 85-384 (a)	70.56	18.2	13.0
Ho 00-961 (b)	77.50	17.7	15.9
HoCP 91-552 (b)	87.14	16.8	15.2

a. Dominant Louisiana Sugarcane Variety. b. High-fiber energy cane variety.
Source: Tew et al., 2007.

While they share the aforementioned similarities, the cane varieties have vastly different end uses, i.e. energy cane has little value in the sugar market and sugarcane has reduced value in the cellulosic ethanol market. Table 1 contains the tonnes of cane harvested per hectare, the percentage of sugar by mass (i.e. brix), and the percentage of insoluble material delivered for processing (i.e. fibre) for two energy cane varieties grown in Louisiana (Ho 00-961 and HoCP 91-552) compared with a traditional sugarcane variety (LCP 85-384) (Tew *et al.*, 2007, Rein, 2006). An additional energy cane variety, L 79-1002, has also been released. Initial reports suggest that this variety generates yields of over 224 MT/ha, which is significantly higher than the 78 MT/ha current varieties are yielding (Tew *et al.*, 2007).

Another factor that could cause sugarcane producers to make the shift into energy cane is the recent increase in input costs, which have driven down the profitability in sugarcane. Although market returns at average yields have more than covered variable production costs, they do not cover total production costs (variable costs plus fixed costs).[7] From 2005 to 2009 net returns per hectare for the average Louisiana sugarcane producer were approximately -$77.5 (Breaux and Salassi, 2005; Salassi and Breaux, 2006; Salassi and Deliberto, 2007, 2008a, 2009). Production of sugarcane has continued because average returns above variable cost are positive ($305 per hectare), allowing producers to cover their costs in the short-run (Breaux and Salassi 2005; Salassi and Breaux 2006; Salassi and Deliberto, 2007; 2008a; 2009). This situation was reversed for 2010, when net return per hectare averaged $150 because of the significant rise in sugarcane price and decline in input costs (Salassi and Deliberto, 2010).

To determine if farmers would be willing to produce energy cane in place of sugar cane, data on both costs of production and output prices is needed. Because the energy cane market is in its infancy, there is inadequate production cost and output price data available for analysis. To address this issue we utilize the *2010 Sugarcane Production in Louisiana* costs and returns report that provides the budget data used for determining sugarcane production costs, since energy cane requires similar production practices as sugarcane and the two crops have a comparable growth cycle (Salassi and Deliberto, 2010). Revenue adjustments reflect the assumption that growers will no longer be paid on the sugar content of the crop, but rather on the total biomass delivered to the processor.

Grower Breakeven Costs

To induce production of energy cane, a biofuel facility/biomass processor would need to pay energy cane growers, at a minimum, a price that on average would cover variable, fixed, overhead, land rental, and transportation costs (i.e. the breakeven price). Breakeven price is determined using equation 1,

$$BE = (fixed + variable + overhead) / \left(\frac{harvested}{100}\right) * tonsperha, \tag{1}$$

where BE is the breakeven price in \$/MT, *fixed* is the fixed cost \$/ha, *variable* is the variable cost \$/ha, *overhead* is the overhead costs in \$/ha, *harvested* is the hectares harvested, and *tonsperha* is the average MT/ha harvested on the operation. Given the similarities between energy cane and sugarcane (production methods and growth), it is expected that the production cost of energy cane will be similar to sugarcane.

Additional assumptions for the model are a one-sixth crop share land rental charge paid by growers to property owners and a payment from the processor to the producer of an average value of $3.85 per tonne for transportation credit from farm to mill (Salassi and Deliberto, 2010). We assume that the producers utilize the typical land rental arrangement of a Louisiana sugarcane producer, and hauling distances represent the average observed in the sugarcane industry (the same data currently utilized in enterprise production cost sugarcane budgets for Louisiana) (Salassi and Deliberto, 2010).

The true yield potential of energy cane is currently unknown, because research and development of energy cane varieties is in its infancy. Consequently, for this analysis we examine yield ranges from 67.2 tonnes (30 short tons) to 156.8 tonnes (70 short tons) per hectare, to allow breakeven price analysis to account for this uncertainty. Uncertainty in energy cane production is not limited to yields, as it is also present in harvesting costs. To reflect the unknown nature of the harvesting cost, we conduct the breakeven analysis over a range of harvesting costs (Tew *et al.*, 2007).[8]

Given that energy cane is a perennial crop, a grower's flexibility is limited by stubbling length, which is the length of the crop cycle (the number of annual harvests possible before replanting is necessary). While stubbling length may be adjusted, the amount it can be adjusted is dependent upon the energy cane variety planted. Since optimal stubbling length varies with variety, we examine both 3rd and 4th stubble, the two most common lengths.[9] For example, if an operation harvests through 3rd stubble, a five-year production cycle is being used.

[7] Appendix A contains the specific variable and fixed costs considered.

[8] Harvesting costs are based on the assumption of 40.5 metric tons per hour can be harvested (Barker, 2007).

[9] For a complete explanation of the stubbling process, please see Mark (2010).

Table 2: Breakeven prices of biomass required to cover energy cane production costs in a five-year crop cycle at various energy cane yields

3rd Stubble		
Yield/Harvested MT/ha	**Breakeven Price (Processer Paying Hauling Costs) ($)**	**Breakeven Price (Producer Paying Hauling Costs) ($)**
67.2	34.60	38.46
78.4	29.52	33.38
89.6	25.74	29.60
100.8	22.82	26.68
112.0	20.48	24.34
123.2	18.57	22.43
134.4	17.21	21.06
145.6	15.69	19.54
156.8	14.54	18.40

Comparison Between Cellulosic and Corn Ethanol

There are two main reasons why corn is currently the major agricultural crop used for US ethanol production: 1) its abundance (supply availability) and 2) the cost of producing ethanol from corn, which is substantially lower than that of cellulosic ethanol. Recent developments have narrowed the production cost gap between corn ethanol and cellulosic ethanol (decreasing enzyme and pre-processing costs) (Aden, *et al.*, 2002; Collins, 2007; Bullis, 2009). For example, in 2007 production costs per litre for cellulosic ethanol were estimated to be $0.70 (Collins, 2007). By 2010, it was expected to decrease to between $0.28 and $0.29 (Aden *et al.* 2002; Collins, 2007). This did not occur as cellulosic ethanol costs are still above $0.52 per litre (POET, 2012). Collins (2007) found that on a percentage basis, capital and enzyme costs were significantly larger portions of the production costs for cellulosic ethanol when compared to corn ethanol.

Ethanol production per ton of biomass varies with the pre-treatment process and the enzyme technology used. For this research, a lignocellulosic ethanol process with an alkaline pre-treatment is assumed for the cellulosic portion of the process, while the juice from the energy cane is fermented using traditional ethanol methods. For these production technologies, it is assumed that each tonne of energy cane produces 94.6 litres of ethanol. Ethanol yield per tonne of biomass can be broken down into sucrose juice ethanol (44 L/MT) and cellulosic ethanol (41 L/MT) (Day, 2010). The total cost for cellulosic ethanol production for the processor is determined using equation 2,

$$TC = FC - BP + EC + OC + CC \qquad (2)$$

where TC is total costs, FC is feedstock costs, BP is by-product revenue, EC is enzyme costs, OC is other costs, and CC is capital costs.

Feedstock procurement accounts for over 70% of the cost of production for a corn ethanol plant. Since this cost is a majority of total costs, and because corn costs have experienced tremendous variation in recent years, two different corn prices are utilized in this analysis. The first price is $145.66 per tonne, which is the average price of corn in the United States for 2009 (USDA 2011). The second price investigated is $275.57 per tonne, which is representative of the high corn prices observed in 2007 and 2011 (USDA, 2011). Collins (2007) and Aden, *et al.* (2002) at the National Renewable Energy Laboratory provide the base by-product, enzyme, capital, and other cost assumptions used in the analysis for the two-ethanol production processes.

3. Results and Discussion

Producer Breakeven

Producer Breakeven for 3rd Stubbling

Table 2 contains the breakeven prices for farmers who grow energy cane on a five-year cycle (harvest through the3rd stubble). At the current yields for energy cane varieties being produced (78.4 MT/ha), growers need to secure a production contract of at least $33.38/MT (column 3, in Table 2). This amount would allow growers to cover costs of production including land rent and transportation. If processors decided to cover the cost of shipment from the farm to the plant, the price required by producers to grow energy cane would fall to $29.52/MT (column 2, in Table 2). It is important to note that Iogen Corporation considered the use of a third party custom hauler for the transportation of biomass from farm to processor (Altman, *et al.*, 2007).[10] Thus, producers under this set of contractual arrangements would only be responsible for planting, growing, and harvesting the crop. As expected, increases in energy cane yield decreases the breakeven price ($/MT) required by producers. Examination of the table shows that the decrease in breakeven cost occurs at a decreasing rate; total cost per tonne is approaching average variable costs as fixed costs are spread out across more tonnes of energy cane. The ability to increase the tonnes per acre to the levels evaluated in this table is possible, and there are reports of these higher yield levels (Somerville *et al.*, 2010)

As observed in table 2, increasing energy cane yields substantially lowers breakeven prices, but this provides only part of the story; we also need to know if the breakeven prices presented in table 2 are sufficient to

[10] Iogen Corporation is a biotechnology firm specializing in cellulosic ethanol. Their corporate headquarters is located in Ottawa, Ontario, Canada. They are considering expansion into the United States in the Pacific Northwest and use wheat straw in their cellulosic ethanol process.

Table 3: Breakeven prices of biomass required to cover energy cane production costs in a six-year crop cycle at various energy cane yields

4th Stubble		
Yield/Harvested MT/ha	**Breakeven Price (Processer Paying Hauling Costs) ($)**	**Breakeven Price (Producer Paying Hauling Costs) ($)**
67.2	31.57	35.43
78.4	26.72	30.58
89.6	23.52	27.38
100.8	20.87	24.72
112.0	18.75	22.61
123.2	17.11	20.97
134.4	15.59	19.44
145.6	14.37	18.23
156.8	13.32	17.17

Table 4: Decline in breakeven prices when farmers grow energy cane on a 4th stubble as opposed to a 3rd stubble basis for various energy cane yields

Yield/Harvested MT/ha	Decline in Breakeven Price (Processer Paying Hauling Costs) ($)	Decline in Processor Costs ($/ha)
67.2	(3.03)	(203.70)
78.4	(2.57)	(201.36)
89.6	(2.20)	(197.53)
100.8	(1.94)	(195.56)
112.0	(1.73)	(193.83)
123.2	(1.57)	(192.84)
134.4	(1.43)	(192.59)
145.6	(1.31)	(190.99)
156.8	(1.23)	(193.58)

attract farmers away from producing sugar cane to producing energy cane. This requires that cellulosic ethanol processors pay a price that would generate at least as much profit as sugar cane. At current sugar prices ($0.10/kg) and expected yields (78.4 MT/ha), sugarcane producers are earning a profit of approximately $2.34/MT. This means that cellulosic ethanol producers would need to pay farmers breakeven plus $2.34 on a per tonne basis. For example, a farmer whose energy cane yield is 100.8 MT/A and works with a processor who pays hauling expense would need to receive $25.16/MT ($22.82/MT+$2.34M/T) for energy cane.

Producer Breakeven for 4th Stubbling

Table 3 shows the breakeven prices required for producers to cover production costs including rent and transportation for a six-year crop cycle (harvest through 4th stubble). As with the shorter crop cycle (Table 2), when yield increases, producers require a lower biomass price per tonne. One of the advantages for producers to switch to a longer stubbling variety is that they are able to spread fixed costs of planting over more years. This reduces the breakeven price for 4th stubble to levels below those observed for harvest through the 3rd stubble at corresponding yields. A second advantage to longer stubbling lengths is that growers harvest more energy cane. Shorter stubbling lengths require farmers to have to replant their cane fields more often, and for both the year the energy cane is planted and the subsequent year no cane is harvested. For example, changing from 3rd stubble to 4th stubble results in an additional 13.8 hectares harvested annually, for the 404.7-hectare (1,000 acre) representative Louisiana farm. As with the harvest through the 3rd stubble, cellulosic ethanol processors would need to pay energy cane producers a premium above breakeven ($2.80/MT) to make the farmers just as well off as if they had produced sugarcane.

Differences in Producer Breakeven Between 3rd and 4th Stubbling

Table 4 illustrates the decrease in breakeven prices if energy cane growers are able to increase the stubbling length from 3rd to 4th stubble. On a per tonne basis, the most significant decrease in price occurs at 67.2 MT/ha. On a per hectare basis, this would save processors $74.82 per hectare. This increase in stubbling length would save processors operating a 37.9 million litre cellulosic ethanol plant approximately $1.1 million a year.[11] The ability to increase the stubbling length is variety dependent (Brown, 2012). As more varieties with greater yields are developed the lower the breakeven price will go. As shown in Appendix A, there is a significant amount of upfront costs to establish energy cane. In Appendix A, we have provided the cost estimates utilized in this estimation. For a more accurate representation, each producer should utilize his or her own costs in equation 1 to estimate a breakeven price for his or her farm. As stubbling length increases in this equation, a larger and larger proportion of the 404.7

[11] This is assuming 67.2 mt/h and 85.8 liters of ethanol per metric ton.

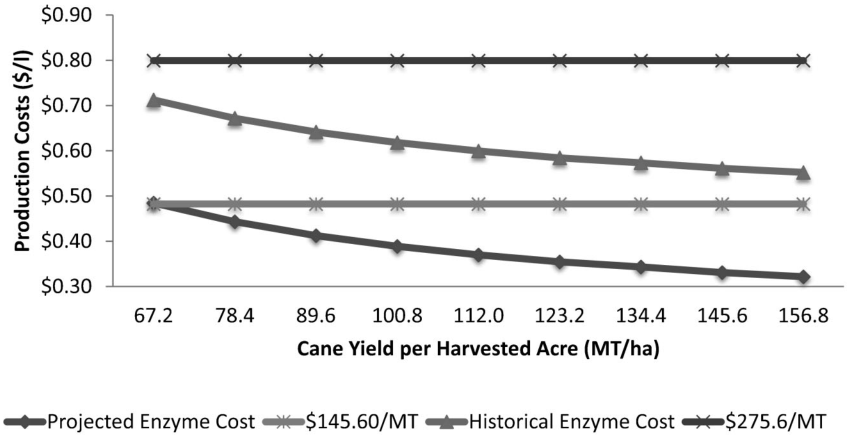

Figure 1: Comparison of ethanol production costs using corn and energy cane (harvest through 3rd stubble) feedstocks for both historical and projected enzyme costs

hectare farm will be harvested on an annual basis, because fewer acres are being left in fallow.

Corn Ethanol Production Costs vs. Cellulosic Ethanol Production Costs

While the previous results provide information on the breakeven prices required by farmers to cover various production costs given energy cane yield and stubble lengths, it is also essential that we examine the choice of ethanol feedstocks from the processors point of view. For cellulosic ethanol to be a viable ethanol production process, the cost to processors must be less than or equal to the costs of manufacturing corn ethanol. The major areas of difference between the two production processes are found in the costs of enzymes and feedstock. In particular, many of the enzymes currently being used in the cellulosic ethanol process are relatively new, and the costs of these enzymes are high. As mentioned previously, it is expected that enzyme costs will fall as more work is done in the cellulosic ethanol arena and enzyme standards are adopted. Consequently we examine both a high enzyme cost of $0.11/l (historical enzyme cost) and a low enzyme cost $0.04/l (projected enzyme cost). Figure 1 shows how cellulosic ethanol production costs compare to the production costs of traditional ethanol when corn is priced at $145.66/MT or $275.57/MT, for both historical and projected enzyme costs. Please note that in figure 1, we are assuming cellulosic ethanol uses energy cane feedstock harvested through the third stubble. Figure 2, contains a similar comparison, except here cellulosic ethanol uses energy cane feedstock harvested through the fourth stubble.

4. Conclusions

For the renewable fuels supply chain to fulfil the mandated 136.3 billion litres of annual biofuel production by 2022, feedstock sources besides corn must be integrated into the supply chain. While corn has historically dominated the ethanol industry, other demands placed on corn stocks for feed grains and human consumption when combined with limited acreage prohibits corn from meeting this mandate alone. Cellulosic ethanol, a biofuel endorsed by EISA to meet this mandate, can be made from a wide variety of feedstocks. For the Southeastern US and in particular

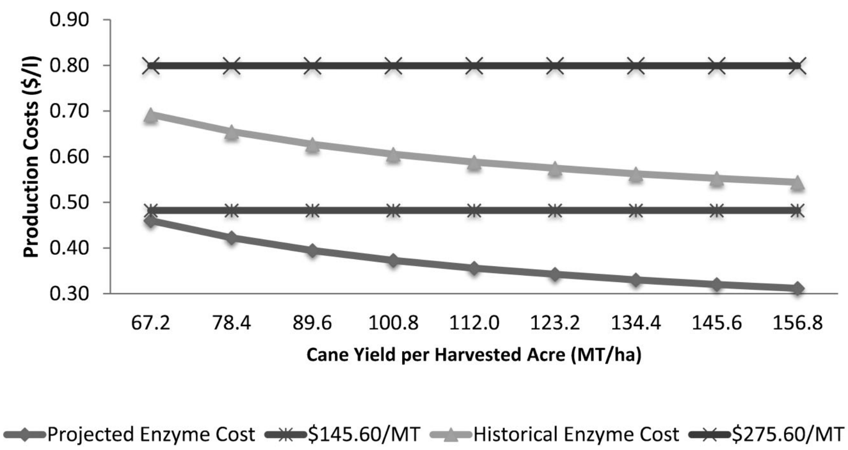

Figure 2: Comparison of ethanol production costs using corn and energy cane (harvest through 4th stubble) feedstocks for both historical and projected enzyme costs

Louisiana, energy cane is a feedstock that appears well suited to help meet this mandate.

Although farmers in Louisiana have not traditionally grown energy cane, its production similarities to sugarcane combined with farmer familiarity with sugarcane make it an attractive option for Louisiana farmers, if they are offered the 'right price' from cellulosic ethanol producers. To find this 'right price' a breakeven analysis was conducted in an effort to provide farmers and ethanol producers with economic information concerning the viability of energy cane as an alternative to sugarcane and as a source of ethanol. The results indicate that both farmers and cellulosic ethanol producers would like to have high yielding varieties with long stubbling lengths. By working with agricultural scientists to develop energy cane varieties that have longer stubbling lengths, farmers would be able to spread out the initial establishment costs of the crop.

While breakeven analysis provides the first economic screen, the breakeven amount is likely an insufficient amount of return for farmers to switch hectares from sugarcane to energy cane. Indeed, the results show that at current sugar prices ($0.10/kg) and yields (78.4 MT/ha) cellulosic ethanol producers must provide farmers an additional $2.34/MT and $2.80/MT on a 3rd and 4th stubbling, respectively if they want farmers to grow energy cane. This premium makes the net revenue on a per hectare basis from energy cane equal to what would be obtained from sugarcane production. Thus, if farmers could have only secured energy cane contracts at breakeven prices, then they would have preferred to stay with sugarcane. We would expect at high yield levels, cellulosic ethanol processors would be more inclined to offer the premium because of decreasing breakeven costs and the constant nature of the price premium.

This result more than any other indicates the need for cellulosic ethanol processors to work with agricultural scientists in developing high yielding varieties. Not only does this decrease the price paid to farmers, it also decreases the number of hectares of energy cane a potential cellulosic ethanol facility needs to operate at a minimum efficient scale (MES). Moreover, this also reduces the biomass transportation costs because there would be a large amount produced in a smaller transportation radius.

Although beyond the scope of this study, we hypothesize that once yields reach a certain threshold, processors will be able to pay the premium for any yields that exceed the threshold. This occurs because as yield increases the breakeven price declines but the premium does not change, and at the threshold yield level, breakeven plus the premium is less than the maximum amount the processor can pay and still make a profit. This model does not incorporate a risk premium for growing energy cane for biomass. The production of energy cane is risky because the market is still in its infancy, which means the market is thin. The risk for growing energy cane as a biomass feedstock is lessened relative to other feedstocks because it can be processed for sugar. Consequently, if the biomass market in the region collapses, the producer would have an alternative market for energy cane. It should be noted that it would not provide the level returns as the traditional sugarcane varieties, because the sugar content is lower than that of sugarcane.

Finally, the competitiveness of cellulosic ethanol with corn ethanol is also investigated in this study. Cellulosic ethanol production is competitive with corn ethanol utilizing projected enzyme prices, irrespective of energy cane yields, stubbling length, and/or corn prices. However, when using historical enzyme costs ($0.11/l), cellulosic ethanol is unable to compete with corn ethanol when corn prices are $145.66/MT, irrespective of energy cane yield or stubbling length. When corn reaches $275.57/MT as it did in 2007 and 2011, the production costs per litre for traditional ethanol exceed $0.79, which is more than the cost of cellulosic ethanol produced from energy cane regardless of energy cane yields or stubbling length.

As enzyme costs continue to decrease, production costs per litre for cellulosic ethanol will decline, which would improve cellulosic ethanol relative to corn ethanol as a profit centre. NREL (2007), Collins (2007), and Day (2010) find that the cost of enzymes and amount of enzymes used will continue to decrease and allow cellulosic ethanol to become more competitive. However, it should be noted that this decrease in enzyme costs would be feedstock and pre-treatment process dependent. Since 2007, enzyme costs for the lignocellulosic ethanol process have fallen by $0.06/l, which has increased the competitiveness of cellulosic ethanol. These results suggest that cellulosic ethanol derived from energy cane should be produced if sufficient biomass exists in an area to operate a MES ethanol plant.

In summary, cellulosic ethanol derived from energy cane could be a source of biofuels in Southeastern US that would help meet the 2022 RFS mandate. Varietal enhancements with respect to yield and stubbling length likely provide the quickest and easiest ways to increase the competitiveness of cellulosic ethanol. As production costs continue to fall over time, as they have done in the corn ethanol industry, cellulosic ethanol could play a pivotal role in the renewable fuel supply chain. Additional research would seek to examine the yield levels of energy cane that would allow cellulosic ethanol producers to pay energy cane farmers the premium above breakeven. The results of this research demonstrate the need for additional work that would investigate ways to increase the competitiveness of the cellulosic ethanol industry.

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Appendix A: Variable and Fixed Cost Components for a Representative 404.7 ha Farm[1]

Field Operation	Variable Costs ($/ha)	Fixed Costs ($/ha)[1]	Total Costs ($/ha)	% of ha in each phase
Fallow Field & Seedbed Prep	$356	$219	$576	20.00%
Cultured Seed Cane	$1,290	$34	$1,325	0.06%
Hand Planting Wholestalk Seed Cane	$639	$187	$826	0.06%
Whole Stalk See Cane Harvest	$169	$128	$297	1.88%
Mechanical Planting Wholestalk Seed Cane	$560	$141	$701	18.12%
Plant Cane Field Harvest	$655	$115	$770	20.00%
1st Stubble Field Operations	$805	$129	$935	20.00%
2nd Stubble Field Operations	$791	$122	$913	20.00%
3rd Stubble Field Operations	$791	$122	$913	20.00%
Harvest for Biomass	$352	$231	$583	78.06%
Overhead	$74	$0	$74	

[1]Assumptions: 78.4 MT/ha, One-sixth land share rent, 3rd Stubbling, Hauling costs not included.

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Exploring the potential and performance of maize production in Bangladesh

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ABSTRACT

Maize is gaining importance in recent years as a promising crop aimed at boosting agricultural growth in Bangladesh. The present study explores the potential of maize expansion by examining its profitability and economic efficiency using a survey data of 300 farmers from three regions. Maize ranks first in terms of yield (7.98 t/ha) and return (BCR=1.63) as compared with rice and wheat. The economic efficiency of maize production is also estimated at a high 87%, although a substantial 15% [(100-87)/87)] cost reduction is still possible while maintaining current output level by eliminating technical and allocative inefficiency. Education positively contributes towards increasing efficiency while large farmers are relatively inefficient. Geography does matter. Efficiency is lower in Bogra region as compared with Dinajpur and Kushtia. Policy implications include investment in education, setting up appropriate price policies to stabilise prices and facilitation of the input markets for timely delivery of required inputs.

KEYWORDS: Economic efficiency; profitability; stochastic cost frontier; maize; Bangladesh

1. Introduction

The Bangladesh economy is dominated by agriculture contributing 14.2% to the Gross Domestic Product (GDP). Of this, the crop sub-sector alone contributes 10.1% to the GDP (BBS, 2011a). Agriculture sector generates about 35.0% of the total foreign exchange earnings (Husain, *et al.*, 2001 and Islam, *et al.*, 2004) and is the main source of employment absorbing 45.6% of the labour force (BBS, 2011a). Land is the most important and scarce means of production resulting in intensive cropping on all available cultivable land. The cropping intensity in 2011 is estimated at a high 191% (BBS, 2011a). It has been increasingly realized that economic development in Bangladesh can not be achieved without making a real breakthrough in the agricultural sector (Baksh, 2003). Although rice is the main staple food grain, maize is gaining importance as a third crop after wheat covering 1.2% and 2.1% of the total and net cropped area in 2011, respectively (BBS, 2011a). The government is also keen to diversify its agriculture and had earmarked 8.9% of the total agricultural allocation (worth US$ 41.8 million[3]) during its Fifth Five Year Plan (1997–2002) (PC, 1998).

Maize in Bangladesh

Maize is one of the oldest crops in the world and is well known for its versatile nature with highest grain yield and multiple uses. In Bangladesh, maize cultivation started in the early 19th century (1809) in the districts of Rangpur and Dinajpur (Begum and Khatun, 2006). During 1962, the then governor of the erstwhile East Pakistan tried to re-introduce maize in those areas but did not succeed. However, the Bangladesh Agricultural Research Institute (BARI) has been conducting research on the varietal development of maize since 1960 with a thrust to develop composite varieties. So far, BARI has developed seven open pollinated and eleven hybrid varieties (Begum and Khatun, 2006; BARI, 2008). The yield potential of the released composite varieties are 5.5–7.0 t/ha and the hybrid varieties are 7.4–12.0 t/ha which are well above the world average of 3.19 t/ha (FAOSTAT, 2011).

Maize production and yield has experienced an explosive growth in Bangladesh in recent years. The cropped area of maize has increased from only 2,654 ha in 1972 to 165,510 ha in 2011; production from 2,249 t to 1,018,000 t; and yield from 0.85 t/ha to 6.15 t/ha during the same period. Maize has now positioned itself as the 1st among the cereals in terms of yield rate (6.15 t/ha) as compared to Boro rice (3.90 t/ha) and wheat (2.60 t/ha) (BBS, 2011a).

Maize possesses a wide genetic variability enabling it to grow successfully in any environment and in Bangladesh it is grown both in winter and summer time, although the former is the dominant pattern. Demand for maize is increasing worldwide and in Bangladesh and its production has crossed one million ton by 2011. A limited number of socio-economic investigations were made on maize cultivation in Bangladesh which revealed that maize is a profitable crop and stands well above from its competitive peers, e.g., rice (Hussain *et al*, 1995; Fokhrul and Haque, 1995)

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[3] In mid-December 2013, US$1 was approximately equivalent to £0.61 and €0.73 (www.xe.com).

and mustard (Haque, 1999) and has brought positive changes in different aspects of livelihood such as capital formation, food intake, income, household amenities, socio-economic conditions, etc (Islam, 2006).

Given this backdrop, the objective of the present study is, therefore, to assess the potential of maize production as an alternative crop by specifically examining profitability, economic efficiency and its determinants at the farm-level in Bangladesh. This is because efficient use of scarce resources is an important indicator in determining potential to increase agricultural production. Although the rice-based Green Revolution technology in Bangladesh has paid off well, there is an urgent need to diversify agriculture in order to sustain its growth (Rahman, 2010). Furthermore, the focus of empirical studies of resource use efficiency in Bangladesh was on rice and wheat (e.g., Rahman, 2003; Coelli *et al*., 2002; Asadullah and Rahman, 2009; Rahman and Hasan, 2008). The importance of assessing economic efficiency of maize arises because although maize cultivation is highly profitable, it requires substantial upfront costs during the production process. Therefore, Bangladeshi farmers characterised with scarce land and credit constraints needs to focus on minimizing production cost while keeping up the high yield potential of the chosen crop in order to sustain their farming practices and benefit from the adoption of this new technology.

The paper is organized as follows. Section 2 describes the methodology and the data. Section 3 presents the results. The final section concludes and draws policy implications.

2. Methodology

Profitability or cost-benefit analysis

Profitability or cost-benefit analysis includes calculation of detailed costs of production and return from maize on a per hectare basis. The total cost (TC) is composed of total variable costs (TVC) and total fixed costs (TFC). TVC includes costs of human labour (both family supplied and hired labour, wherein the cost of family supplied labour is estimated by imputing market wage rate), mechanical power; seed, manure, chemical fertilizers; pesticides; and irrigation. TFC includes land rent (if owned land is used then the imputed value of market rate of land rent is applied) and interest on operating capital. The gross return (GR) is computed as total maize output multiplied by the market price of maize. Profits or gross margin (GM) is defined as GR–TVC, whereas the Net return (NR) is defined as GR–TC. Finally, the Benefit Cost Ratio (BCR) is computed as GR/TC.

Analytical framework: the stochastic cost frontier model

A limitation of profitability analysis presented above is that it does not tell us whether farmers are achieving the maximum potential yield and profit from their production process. However, an analysis of economic efficiency allows such information to be generated at the individual producer level which is important for farmers, policy makers and other stakeholders alike.

A cost function, which is a dual of the underlying production function, is defined as a function of input prices and output level. Specifying a cost function avoids the problem of endogeniety of variables used in modelling. This is because input prices are considered exogenous in nature and is not determined within the model. A conventional cost function assumes perfect efficiency in production which is not a valid assumption given widespread evidence of inefficiency in agricultural production process worldwide (e.g., Bravo-Ureta *et al*., 2007). However, specification of a stochastic cost frontier function allows us to identify the level of inefficiency (specifically economic inefficiency) in the production process at the individual producer level.

Economic efficiency, also known as cost efficiency, results from both technical efficiency and allocative efficiency. Technical efficiency refers to a producer's ability to obtain the highest possible output from a given quantity of inputs (Rahman, 2003). Allocative efficiency refers to a producer's ability to maximise profit given technical efficiency. A producer may be technically efficient but allocatively inefficient (Hazarika and Alwang, 2003). Therefore, economic/cost efficiency refers to a producer's ability to produce the maximum possible output from a given quantity of inputs at the lowest possible cost.

Consider the stochastic cost frontier function based on the composed error model (e.g. Aigner *et al*., 1977);

$$\ln C_i = \alpha_0 + \alpha \ln Q_i + \sum_{j=1}^{n} \beta \ln W_{ij} + \varepsilon_i \qquad (1)$$

where C_i represents household i's cost per ha maize production, Q_i denotes the maize output per ha; W_{ij} signifies the household-specific price of variable input i, and ε_i is a disturbance term consisting of two independent elements as follows:

$$\varepsilon_i = u_i + v_i \qquad (2)$$

v_i, assumed to be independently and identically distributed as $N(0,\sigma_v^2)$, represents random variation in cost per acre due to extraneous factors such as the weather, crop diseases, and statistical noise. The term u_i is taken to represent cost inefficiency relative to the stochastic cost frontier, $\ln C_i = \alpha_0 + \alpha \ln Q_i + \sum_{j=1}^{n} \beta \ln W_{ij} + v_i$. It is, therefore, one-sided as opposed to being symmetrically distributed about the origin. In other words, $u_i=0$ if costs are, ceteris paribus, as low as can be, and $u_i>0$ if cost efficiency is imperfect. u_i is assumed to be identically and independently distributed as truncations at zero of the normal distribution $N(\mu,\sigma_u^2)$, The stochastic cost function (1), may be estimated by maximum-likelihood. Given the above distributional assumptions,

$$E(u_i|\varepsilon_i) = \frac{\sigma\lambda}{(1+\lambda^2)}\left[\frac{\phi(\mu_i^*)}{1-\Phi(\mu_i^*)} - \mu_i^*\right] \qquad (3)$$

where ϕ and Φ denote, respectively, the standard normal p.d.f. and the standard normal c.d.f., $\lambda = \sigma_u + \sigma_v$, $\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$, and $\mu_i^* = (\varepsilon_i \lambda/\sigma) + (\mu/\sigma\lambda)$ (Hazarika and Alwang, 2003). Replacing ε_i in the above expression by the regression residual and the other parameters by their ML estimates yields an estimate, u_i, of farm-specific cost inefficiency (Jondrow *et al.*, 1982).

Next, in determining the predictors of cost inefficiency, we use the single stage approach proposed by Battese and Coelli (1995) wherein the cost inefficiency parameter (u_i) is specified as a linear function of farm-specific managerial and household characteristics subject to statistical error, such that:

$$u_i = \sum_{k}^{m} \delta Z_i + \zeta_i \geq 0, \quad (4)$$

where, Z_i are the farm-specific managerial and household characteristics and the error ζ_i is distributed as $\zeta_i \sim N(0,\sigma^2_\zeta)$. Since $u_i \geq 0, \zeta_i \geq -\delta Z_i$, so that the distribution of ζ_i is truncated from below at the variable truncation point, $-\delta Z_i$ (Rahman and Hasan, 2008).

Study areas and the sample farmers

Maize is cultivated almost all over the country, though the intensity of planted area and land suitability are not equal in all regions. Therefore, we computed a maize area index for each greater district.[4] The maize area index for the *j*th district is expressed as:

$$MAI_j = (Area_j / GCA_j) * 100, \quad (5)$$

where *MAI* is the maize area index, *Area* is the maize area and *GCA* is the gross cropped area. Based on this index, maize growing regions were classified into three levels of intensity: high intensity (MAI $\geq$ 1.00), medium intensity (1.00 $<$ MAI $\geq$ 0.50), and low intensity areas (MAI $<$ 0.50).

A multistage sampling procedure was adopted to select the sample farmers. First, three areas were selected according to the rank of *MAI* as well as percent of total winter maize area. The selected regions are Kushtia, Bogra and Dinajpur which covered 59% of total maize area of the country. In the second stage, one new district was chosen from each aforesaid selected greater district according to higher percent of maize area and ease of communication. Then, one upazila (sub district) from each new district and one union from each upazila were selected purposively. Finally, three villages (one from each union) were selected randomly for collection of primary data. In the third stage, a number of steps were followed to select the households to ensure a high level of representation. At first, a list of all maize growing farmers was collected from the Department of Agricultural Extension (DAE). Then, these farm holdings were stratified into three standard farm-size categories commonly adopted in Bangladesh (e.g., Rahman and Hasan, 2008). Then, a total of 300 maize producing households were selected following a standard stratified random sampling procedure. Structured questionnaire was administered for data collection which was pre-tested prior to finalization. Data on production technologies of maize, inputs, outputs and prices were recorded seasonally by three visits covering the crop season. First visit was done just after sowing of seeds, second visit following completion of all intercultural operations and the last one after harvesting and threshing of the crop. Data also includes socio-economic profile of the sampled farmers. The survey covered winter maize growing period from November 2006 to April 2007.

The empirical model

An extended general form of the Cobb-Douglas stochastic cost frontier function is used.[5] This was done in order to include variables representing environmental production conditions within which the farmers operate (e.g., Sherlund *et al.*, 2002; Rahman and Hasan, 2008). Hence, the model is written as:

$$\ln C_i^* = \alpha_0 + \alpha \ln Q_i + \sum_{j=2}^{14} \beta \ln W_{ij}^* + \sum_{l=1}^{2} \omega E_{il} + \sum_{d}^{5} \tau D_{id} + u_i + v_i \quad (6)$$

and

$$u_i = \delta_0 + \sum_{k=1}^{10} \delta Z_{ik} + \zeta_i \quad (7)$$

where C^*_i is the total cost of maize cultivation normalized by one of the input prices[6] (Muriate of Potash price), W^*_{ij} is *j*th normalized price of the *j*th input for the *i*th farmer; D_{id} is the *d*th dummy variable used to account for zero values of input use and have the value of 1 if the *j*th input used is positive and zero otherwise[7]; E_{il} is the *l*th dummy variable representing environmental production conditions, v_i is the two sided random error, u_i is the one sided half-normal error, *ln* natural logarithm, Z_{ik} is the *k*th variable representing managerial and socio-economic characteristics of the farm to explain cost inefficiency, ζ_i is the truncated random variable; α_0, α, β, ω, τ, δ_0, and δ are the parameters to be estimated.

One unique feature of maize cultivation in Bangladesh is the use of a wide range of inorganic fertilizers, organic fertilizer and other modern inputs. As a result, a total of 14 input prices (W), two environmental production condition variables (E), and five dummy variables (D) to account for zero use of inputs are used in the cost frontier model, and 10 variables representing managerial and socio-economic characteristics of the farmer along with two regional dummy variables (Z) are included in the inefficiency effects model as predictors of cost inefficiency. Table 1 presents the definitions, units of measurement, and summary statistics for all the variables.

Limitation of the parametric approach used

One limitation of adopting a stochastic cost frontier approach is that it requires assumptions regarding

[4] Although there are 64 districts in Bangladesh, most secondary data are still reported at the level of these 21 former greater districts.

[5] We did not use the translog model because of the limited sample size and the large number of explanatory indicators (22 in the cost frontier model). Moreover, Kopp and Smith (1980) suggest that the choice of functional form has a limited effect on efficiency. Consequently, the Cobb-Douglas specification is widely used in production or cost frontier studies (e.g., Hazarika and Alwang, 2003; Rahman and Hasan, 2008; Asadullah and Rahman, 2009; Alene, 2007).

[6] The Muriate of Potash price (Taka/kg) was used for normalization of total cost and all other input prices. The homogeneity condition is imposed by this normalization.

[7] In this study, inputs that contain zero values for some observations are specified as *ln* {*max* (X_j, 1 – D_j)} following Battese and Coelli (1995).

Table 1: Definition, measurement and summary statistics of variables

Variables	Measure	Mean	Standard deviation
Dependent variable			
Cost of maize production	Taka per ha	44411.22	3,722.71
Output			
Maize output	Kg per ha	7897.97	561.34
Input prices			
Muriate of Potash price[a]	Taka per kg	14.24	0.81
Urea price	Taka per kg	6.11	0.42
Zinc sulphate price	Taka per kg	61.09	13.30
Gypsum price	Taka per kg	4.12	0.52
Borax price	Taka per kg	50.78	12.53
Triple Super Phosphate price	Taka per kg	16.27	2.48
Mixed fertilizer price	Taka per kg	13.13	0.49
Manure price	Taka per kg	0.39	0.05
Pesticide price	Taka per ha	651.00	328.81
Labour wage	Taka per person-day	76.10	6.78
Mechanical power price	Taka per ha	4146.16	676.47
Seed price	Taka per kg	159.83	27.31
Irrigation price	Taka per ha	3210.22	852.42
Land rent	Taka per ha	11516.64	1,672.30
Cow dung users	Dummy (1=Yes, 0=No)	0.51	--
Pesticide users	Dummy (1=Yes, 0=No)	0.52	--
Gypsum users	Dummy (1=Yes, 0=No)	0.60	--
Borax users	Dummy (1=Yes, 0=No)	0.53	--
Mixed fertilizer users	Dummy (1=Yes, 0=No)	0.26	--
Environmental factors			
Land suitability	Dummy (1=Medium high land or High land – suitable, 0 otherwise)	0.99	--
Soil type	Dummy (1=loamy, sandy loam or clay loam, 0 otherwise)	0.65	--
Regional dummies			
Dinajpur region	Dummy (1=Yes, 0=No)	0.33	--
Bogra region	Dummy (1=Yes, 0=No)	0.33	--
Managerial variables			
Area under maize	ha	0.79	0.80
Age of the farmer	Years	40.94	11.06
Education of the farmer	Completed years of schooling	5.44	4.35
Experience in growing maize	Years	6.47	5.45
Family size	Persons per household	5.43	2.28
Sowing date	Dummy (1=if sown during optimum time, 0 otherwise)	0.56	--
Variety	Dummy (1=if 900M variety is used, 0 otherwise)	0.51	--
Link with extension services	Dummy (1=if had extension contact or received training on maize production, 0 otherwise)	0.48	--
Total number of observations		300	

Note: Muriate of Potash price is used to normalize total cost and all other input prices for the regression analysis.
Exchange rate of USD 1.00=Taka 68.80 in 2006-07 (BB, 2010).
Source: Field survey 2007.

specification of the production technology and behaviour of the market and the producer. We have specified an extended Cobb-Douglas cost function to represent the true underlying technology which does not allow any interaction amongst input variables and assumes market to be perfectly competitive and impose cost minimizing behaviour on the part of the producer. Since maize is produced mainly for sale, these assumptions seem quite logical. In fact, market for agricultural products (e.g., maize) closely approximate perfectly competitive market since buyers and sellers cannot dictate price and the products are homogenous in nature. Therefore, we are quite confident that our approach portrays real situation quite closely and is a valid approach.

3. Results

Profitability of maize

Profitability of maize cultivation by regions is presented in Table 2. The highest cost component is human labour followed by chemical fertilizers and mechanical power services. Land rent, which is a fixed cost element, is also very high and represents a real burden particularly for tenants and landless farmers. It is clear from Table 2 that although there are significant regional variations in all elements of costs and returns, the Benefit-Cost Ratio (BCR) is very high estimated at 1.63. The comparable estimates of BCR for wheat is 1.40 (Hasan, 2006) and Boro rice (dry winter season) is 1.14 (Baksh, 2003)

Table 2: Cost, return and profitability of maize production

Items	Taka per hectare				F-test for regional differences[a]
	Bogra	Kushtia	Dinajpur	All regions	
Human Labour	12342	11661	9590	11198	117.84***
Mechanical power	4678	4257	3503	4146	160.13***
Seed	3119	3323	3551	3331	14.78***
Manure	1079	809	2939	1609	79.95***
Chemical fertilizers	9327	9363	7281	8657	53.54***
Pesticides	814	270	90	391	114.22***
Irrigation	3032	3772	2825	3210	40.29***
Interest on operating capital	372	375	310	352	12.55***
Land rent	11205	10718	12627	11517	41.09***
Total variable cost (TVC)	34391	33455	29780	32542	56.66***
Total cost (TC)	45968	44548	42717	44411	20.37***
Gross Return (GR)	74145	80177	62766	72363	215.17***
Gross Margin (GM=GR-TVC)	39754	46722	32986	39821	127.94***
Net return (NR=GR-TC)	28177	35629	20050	27952	132.77***
Benefit-Cost Ratio (BCR=GR/TC)	1.61	1.80	1.47	1.63	103.33***

Note: [a]=One-way ANOVA using the Generalised Linear Model (GLM).
***significant at 1 percent level ($p<0.01$).
Source: Field survey 2007.

thereby, establishing that maize stands high in terms of returns amongst major cereals in Bangladesh. Also, maize ranks first in terms of yield estimated at 7.97 t/ha (Table 1) as compared to wheat at 2.40 t/ha (Hasan, 2006) and Boro rice at 5.05 t/ha (Baksh, 2003).

Determinants of maize production cost

Parameter estimates of the stochastic cost frontier along with inefficiency effect model are reported in Table 3 using the Maximum Likelihood Estimation (MLE) procedure in STATA Version 8 (STATA Corp, 2003). First we checked the sign of the third moment and the skewness of the Ordinary Least Squares (OLS) residuals of the data in order to justify the use of the stochastic frontier framework (and hence the MLE procedure).[8] The computed value of Coelli's (1995) standard normal skewness statistic (M3T) based on the third moment of the OLS residuals is 1.77 ($p<0.10$) H_0: M3T=0. In other words, the null hypothesis of no inefficiency component is rejected and, therefore, the use of the stochastic frontier framework is justified. The significant value of the coefficient on γ reported in Table 3 also strongly suggests presence of cost inefficiency.

Cost per ha of maize production significantly increases with maize output as expected ($p<0.01$). Most of the signs on the coefficients of input prices are positive consistent with theory. The two negative signs on the coefficients of gypsum and land rent variables are not significantly different from zero and may not be the true relationship. Since Cobb-Douglas model is used, the coefficients on the variables can be directly read as cost elasticities. The coefficient on the output variable is 0.41, indicating that a one percent increase in output level will increase cost by 0.41%. Cost per ha of maize production significantly increases with the use of labour, mechanical power, seed, irrigation, pesticides, Triple Super Phosphate (TSP), Zinc sulphate, and manure. The elasticity values of mechanical power and labour are the highest estimated at 0.17 and 0.16 indicating that a one percent rise in the prices of these inputs will increase the cost of producing maize by 0.17% and 0.16%, respectively. Similarly, a one percent rise in the cost of TSP and zinc sulphate fertilizers will increase maize production cost by 0.12% and 0.09%, respectively. Movement in other fertilizer prices (e.g., urea, borax, mixed fertilizers and gypsum) do not seem to have a statistically significant influence on the production cost of maize.

It is surprising to see lack of the influence of environmental variables. One reason may be that 99% and 65% of the farmers are cultivating maize on the most suitable land (in terms of elevation) and soil type, respectively (Table 1). Controlling for the non-use of some inputs are justified as indicated by the significant coefficients on the dummy variables ($p<0.01$ to $p<0.10$). Also the formal joint test of hypothesis of no effect of controlling dummies were strongly rejected at 1 percent level ($\chi^2_{(5,\ 0.99)}=166.17$, $p<0.01$).

Economic inefficiency in maize production and its determinants

The economic/cost efficiency of maize cultivation is estimated at 87% implying that 15% [(100-87)/87] of cost reduction is still possible while maintaining current level of output by removing technical and allocative efficiency (Table 4). Our estimate is at the higher end of the range seen in the literature (e.g., Alene, 2007; Hazarika and Alwang, 2003; Rahman and Hasan, 2008; Coelli *et al.*, 2002; Bravo-Ureta *et al.*, 2007) implying that maize also performs relatively better than rice and wheat, particularly in Bangladesh (e.g., Rahman and Hasan, 2008; Coelli *et al.*, 2002). The cost efficiency ranges between 67% to 99% percent and three-quarter of

[8] In the stochastic frontier framework, the third moment is also the third sample moment of the u_i. Therefore, if it is negative, it implies that the OLS residuals are negatively skewed and technical inefficiency is present.

Table 3: Joint parameter estimates of the stochastic cost frontier with inefficiency effects model

Variables	Parameter	Coefficient	t-ratio
Stochastic cost frontier model			
Constant	α_0	4.5847***	16.35
Maize output level	α_1	0.4164***	7.51
Normalized input prices			
Urea price	β_2	0.0065	0.45
Gypsum price	β_3	-0.0517	-1.42
Borax price	β_4	0.0550	1.44
Triple Super Phosphate price	β_5	0.1220***	3.87
Zinc sulphate price	β_6	0.0927***	3.63
Mixed fertilizer price	β_7	0.1084	1.47
Manure price	β_8	0.0831***	3.01
Pesticide price	β_9	0.0666***	9.75
Labour wage	β_{10}	0.1617***	3.99
Mechanical power price	β_{11}	0.1676***	5.60
Seed price	β_{12}	0.0933***	4.55
Irrigation price	β_{13}	0.1146***	10.01
Land rent	β_{14}	-0.03374	-1.49
Cow dung users	τ_1	0.0599***	6.79
Pesticide users	τ_2	0.0502***	6.64
Gypsum users	τ_3	0.0401***	3.73
Borax users	τ_4	0.0016	0.13
Mixed fertilizer users	τ_5	-0.0331*	-1.78
Environmental factors			
Land suitability	ω_1	-0.0110	-0.96
Soil type	ω_2	0.0015	0.19
Variance Parameters			
$\sigma^2=\sigma_u^2+\sigma_v^2$	σ^2	0.0042***	11.27
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	γ	0.99***	121.00
Log likelihood		433.524	
Wald χ^2 (21 df)	χ^2	7480.58***	
Inefficiency effects function			
Constant	δ_0	0.1146***	4.40
Maize area	δ_1	0.0115*	1.81
Age of the farmer	δ_2	-0.0002	-0.60
Education of the farmer	δ_3	-0.0018*	-1.66
Experience in growing maize	δ_4	-0.0006	-0.28
Family size	δ_5	-0.0025	-1.22
Sowing date	δ_6	-0.0095	-1.02
Variety	δ_7	0.0087	0.93
Link with extension services	δ_8	0.0024	0.20
Dinajpur region	δ_9	0.0113	0.70
Bogra region	δ_{10}	0.1496***	4.72
Total number of observations		300	

Note: *** significant at 1 percent level ($p<0.01$).
**significant at 5 percent level ($p<0.05$).
*significant at 10 percent level ($p<0.10$).

the farmers were operating at an efficiency range above 80% which is very encouraging.

The predictors of economic inefficiency are presented at the lower panel of Table 3. The joint test of hypothesis of no inefficiency effects was strongly rejected at 1 percent level ($\chi^2_{(10,\ 0.99)}=35.93$, $p<0.01$). Education of the farmers significantly improves efficiency while large farmers are relatively cost inefficient which are consistent with the existing literature (e.g., Alene, 2007; Asadullah and Rahman, 2009). Use of optimal variety (i.e., 900M) or sowing during optimum date has no significant influence on cost inefficiency. However, geography does matter. Farmers in Bogra region are relatively inefficient as compared to their Dinajpur and Kushtia peers. The reason may be due to differences in micro-climate, soil type, other regional factors as well as production practices of the farmers. For example, farmers from Bogra used lowest doses of chemical fertilizers (except urea) as compared with farmers from Dinajpur and Kushtia. Similarly, the use rate of organic manure by farmers in Bogra is about a quarter of the amount applied by farmers in Dinajpur and Kushtia.

4. Conclusions and policy implications

The present study assessed the potential for maize expansion by examining profitability and economic efficiency of maize producers in Bangladesh using an extended Cobb-Douglas stochastic cost frontier model. Our results demonstrate that yield and profitability of maize is higher than rice and wheat. The cost of maize production increases significantly with increase in input prices and output level. The level of economic efficiency is also relatively high at 87% although scope still exists to reduce cost by 15% by eliminating technical and allocative

Table 4: Cost efficiency distribution

Items	Percentage of farmers
Efficiency levels	
up to 60%	0.00
61–70%	1.70
71–80%	20.30
81–90%	44.00
91% and above	34.00
Mean efficiency by farm size	
Large farms	0.85
Medium farms	0.87
Small farms	0.87
Mean efficiency by region	
Kushtia	0.91
Dinajpur	0.90
Bogra	0.79
Overall	
Mean efficiency score	0.87
Standard deviation	0.07
Minimum	0.67
Maximum	0.99

inefficiency while maintaining current production level. Education has a significant influence on reducing inefficiency while large operation size increases this.

The policy implications are clear. Facilitation of the input markets by setting appropriate price policies would significantly reduce cost of production and raise profitability of the farmers. High price of good quality seed and TSP fertilizers and low price of maize were ranked as the 1st, 4th and 6th major constraints by these maize growers. Wide variation in input prices presented in Table 1 further proves that farmers indeed face highly variable farm-specific input prices. The reasons may be due to market imperfections and/or lack of infrastructure for timely delivery of inputs resulting in highly variable input prices. The Directorate of Marketing (DAM) and Bangladesh Agricultural Development Corporation (BADC) of the Ministry of Agriculture have an important role to play in this regard. DAM can play a role in stabilising prices while BADC can expand/improve on its traditional role of supplying inputs to farmers at the right time and in right quantities, which in turn will support price stability.

Investment in education targeted at farmers will significantly improve economic efficiency. Literacy rate in Bangladesh is on the rise, estimated at 57.7% in 2010 (defined as population aged 7 years and over who can read and write) (BBS, 2011b) which is partly due to government sponsored adult literacy program since the early 1980s, strengthening of state run universal primary education as well as several thousand fixed term primary schools run by BRAC (a leading NGO) and other NGOs. The average level of education of farmers in our sample is just above the primary level qualification (Table 1). Asadullah and Rahman (2009) noted that the impact of education on efficiency kicks in when farmers' education level lies between primary and secondary level education. Therefore, the Ministry of Education has an important role to play in creating opportunities for secondary level education which will enable farmers to gain more out of their production processes. Also with easy access of cell phone technology throughout Bangladesh, the adult literacy program can be further strengthened and disseminated to farmers effectively. For example, the existing tenant farmer scheme of BRAC provides an institutional set up which can make this feasible along with NGO run learning centres in rural communities.

The geographical variation in production performance of farmers may be due to a number of factors such as micro-climate, soil types, high input costs and/or differences in production practices which needs further investigation. Nevertheless, maize has strong potential and should be promoted. A boost in maize production could significantly curb dependence on rice as the main staple in Bangladeshi diet, which is a goal worth pursuing.

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Economic evaluation of a range of options for the management of soiled water/dilute slurry on Irish dairy farms

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ABSTRACT

Dairy soiled water (DSW) is water collected from concreted areas, hard stand areas and holding areas for livestock that has become contaminated by livestock faeces or urine, and parlour washings and must be managed in compliance to the Nitrates Directive S.I.610.2010. The objectives of this study were to evaluate the economic outcomes from a range of options for the management of DSW on Irish grass based dairy production systems. The management options evaluated were DSW stored separately for 10 days, DSW recycled using a woodchip and a sand filter, and DSW mixed together with slurry. The different options investigated centred around contrasting methods of DSW storage and application. The overall mean net costs for storage, treatment and application were €242, €1536 and €849 respectively[4]. The mean savings were €15 per cow across management options, consisting of savings from fertiliser, water, increased herbage DM production. The management option of storing DSW with slurry had higher savings compared to MO1 and MO2, which were attained from extending the grazing season length, using low cost storage and application methods combined with strategic application during the growing season for optimum NFRV and DM response.

KEYWORDS: dairy soiled water; dilute slurry management; woodchip filter

1. Introduction

Worldwide demand for dairy products is expected to rise as a result of global population growth and projected increases in per capita disposable income (Donnellan *et al.*, 2011). In the Republic of Ireland, dairy output represents 30% of all Irish agri-food exports (Department of Agriculture, Food and Fisheries, 2012 a). Dairy production in Ireland is characterised by a seasonal spring calving system with the objective of high utilisation of grazed grass in the diet (Dillon *et al.*, 2008) and these systems have economic (Shalloo *et al.*, 2004) and environmental advantages (Ryan *et al.*, 2012). In Ireland and Europe, the dairy industry is currently experiencing a period of change, with the impending removal of milk quotas in 2015. In the Republic of Ireland this change will result in increased pressure for dairy systems to maximise the economic returns, in the context of a milk price that is more volatile, as the interaction between dairy product supply and demand interact (Donnellan *et al.*, 2011). Increasing overall dairy cow numbers facilitated by increasing stocking rates should be focused on increased grass utilisation which will increase the overall dairy enterprise profitability (Shalloo *et al.*, 2007). This increase in cow numbers on farms will lead to the production of greater volumes of dairy soiled water (DSW), which will require effective environmental and economically sustainable management options. Within the European Union, there has been increasing regulatory pressure to lower losses of nitrogen (N) to water and to the environment, through national regulations stemming from the Nitrates Directive and Water framework Directive (Council of the European Communities, 1991).

Dairy soiled water is water collected from concreted areas, hard stand areas and holding areas for livestock that has become contaminated by livestock faeces or urine, and parlour washings and must be managed in compliance to the Nitrates Directive (Minogue *et al.*, 2010). Dairy soiled water contains valuable but variable levels of nutrients such as N and phosphorus (P) (Minogue *et al.*, 2010). Soiled water is legally defined in Ireland as having a five day biochemical oxygen demand (BOD) of <2,500 mg L^{-1}, <1% dry matter (DM), has a minimum storage requirement of 10 days and can be applied all year round based on the Nitrates Directive requirements (SI No.610, 2010). Minogue *et al.*, (2010), investigated DSW on Irish dairy farms and found that 73% and 87% of samples complied with the legal definition of soiled water based on the BOD (mean

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[4] In mid-December 2013, €1 was approximately equivalent to $1.38 and £0.84 (www.xe.com)

Table 1: Description of spring calving dairy system

Dairy System Description	
Average number of cows	80
Mean calving date	17 February
Mean dry off date	18 December
Milk yield per cow (kg/cow)	5356
Milk fat%	4.38
Milk protein%	3.56
Milk solids yield (kg MS/cow)	414
Stocking rate (LU/ha)	2
Grazed grass intake (kg DM/cow)	3110
Silage intake (kg DM/cow)	1333
Concentrate intake (kg DM/cow)	408
Culling%	17.8
Average Live weight (kg/cow)	535

2246 mg l^{-1}) and DM (mean DM 0.5%) content respectively.

In the Republic of Ireland all farmers are obliged to observe the requirements of the Nitrates Directive including those for minimum slurry storage capacity. Where livestock excreta and soiled water are mixed in a collecting yard tank or slurry tank, this material is characterised as slurry and cannot be spread during the closed period (SI 610, 2010). Alternative management strategies such as the use of aerobic woodchip filter (Ruane *et al*., 2011) and sand filter (WSF) (Ruane *et al*., 2012) to remove organic matter, suspended solids (SS) and nutrients from DSW, would allow the re-use of the filtered effluent to wash down yards. This would reduce the total water usage and environmental risks associated with land spreading. The use of such a bio-filtration system creates a synergistic opportunity from both an economic and environmental perspective to reduce costs associated with water use and also to maximise the potential from nutrients in the slurry.

The objectives of this study were to evaluate the economic outcomes from a range of options for the management of soiled water/dilute slurry on Irish grass based dairy production systems. The management options investigated the economic effect of contrasting storage and application methods, combined with a range of storage periods. The effect of application timing, agronomic response, and fertiliser replacement value were included in the analysis. The investigation combined the production and economic interactions and consequences of DSW management options, based on alternating grazing season lengths in grass based seasonal calving dairy production systems. The options investigated were; storing DSW for a minimum of 10 day's (MO1), recycling DSW using a WSF (MO2), and storing DSW in the existing on farm winter slurry storage facilities (MO3). The different options investigated centred around contrasting methods of DSW storage, treatment and application, to assess the most economic and environmentally viable management option for DSW.

2. Materials and Methods

Dairy Soiled Water (DSW) model description

The DSW model described in this paper is a simulation model developed to assess the economic consequences of different management practices relating to DSW management practices in pasture based seasonal calving dairy production systems. The different DSW management practices investigated in the model include; DSW storage method, storage period, DSW application method, application timing, DSW filtration and water recycling. The management practices were evaluated to assess the effect on costs, savings, and farm profitability. The different management options were investigated under different scenarios described below.

Dairy production system physical performance

The physical profile of the dairy system simulated was obtained from 3 years of research data (Ryan *et al*., 2012) conducted at Dairygold Research Farm, at Moorepark, Animal and Grassland Research and Innovation Centre, Fermoy, Co Cork. Farm system production data were generated by the MDSM (Shalloo *et al*., 2004) based on the system's physical performance profile (Ryan *et al*., 2012) to simulate a grass based dairy production system with a mean calving date of 17th of February and a mean lactation length of over 300 days. The dairy systems simulated were the same for all options investigated (Table 1).

DSW model description: Dairy soiled water nutrient value

Dairy soiled water is produced on Irish dairy farms through the washing-down of milking parlours and holding areas. It contains nutrients and other constituents that provide potential in relation to reduced costs and increased profitability. The characteristics (volume and nutrient content) of DSW produced on Irish dairy farms used in the DSW model are based on the findings of Minogue *et al*., (2010). Minogue *et al*., (2010), noted on average, 9784 l of DSW are produced per cow $year^{-1}$, containing 0.5% DM, 587, 80, 568 and 2246 mg l^{-1} of N, P, K and BOD respectively.

DSW model description: DSW storage and application

In the economic assessment, a variety of waste water storage, treatment and application practices were investigated. The construction and maintenance/running costs associated with different forms of waste water storage were based on average costs (DAFF 2006, 2007;

Table 2: Average Fertiliser Nitrogen (N), Phosphorus (P), Potassium (K), tap water and grazed herbage DM costs

Item	Average value €/T
Calcium ammonium nitrate (CAN) 27.5%N	€330
Urea 46% nitrogen	€400
Super-phosphate (16% P)	€425
Muriate of potash 50% K	€450
Tap water	€3
Grazed herbage DM	€127

O'Sullivan, 2012; Ryan 2012). The different types of waste water storage investigated were, waste water stored in concrete tanks (CT), waste water stored in over-ground circular slurry/effluent store (ST) and waste water stored in a geomembrane-lined lagoon (LT). The specifications of the storage facilities were based on the S123, S122 and S126 for CT, ST and LT respectively (DAFF 2006). These are the standard types of waste water and slurry storage facilities used in Ireland (Hyde *et al.*, 2006). Costs were calculated based on the average construction, deprecated over the recommended lifetime of the structure (DAFF 2006, 2007; O'Sullivan, 2012; Ryan 2012). The average cost per m^3 of storage capacity used for constructing a CT, LT and LT were €80, €37 and €30 and the lifetime of the structures were estimated at 20 years (DAFF 2006, 2007; O'Sullivan, 2012; Ryan 2012).

The DSW application methods investigated in the economic analysis were, the use of a contractor using a vacuum tanker (TA), a contractor using a umbilical spreading system (UA) and an on farm waste water pump and irrigator system (IA). The average costs used for the different methods of application were based on O'Sullivan, (2012) and industry average estimates. The TA and UA application costs were €55 and €150 per hour with the application capacity of 45.4 m^3 and 136.3 m^3 per hour respectively. There was an additional cost associated with the use of the UA application method, due to the initial setting up and laying out pipes etc, there was a minimum charge of €750 (5 hours work). The IA costs associated with on-farm fixed irrigator pump and application system, were the initial installation cost of €8,000 for pump, piping and irrigator applicator, capable of pumping 4 m^3 per hour for 4 hours each day with an average electricity usage of 2200 KWH year with a running cost of €0.181 per KWH and the lifetime of the equipment was estimated at 8 years. In the management options investigated, the IA was only used for applying DSW with a DM$<$0.5% which is the typical practice undertaken in Irish farms for DSW.

DSW model description: DSW treatment and recycling

Data used to simulate the performance of a WSF using wood chip and sand filters were based on the findings of Ruane *et al.*, (2011) and Ruane *et al.*, (2012). Ruane *et al.*, (2011) observed a reduction in chemical oxygen demand (COD) of 66% and nutrient removal rates of 57% and 31% for total nitrogen (TN) and phosphorus (P) respectively using woodchip. Ruane *et al.*, (2012) used a sand filter to further treat DSW exiting the woodchip filter, to produce an effluent capable for the re-use in washing yards. The COD was reduced by 56% and nutrient removal rate were 57% and 74% for TN and P respectively. An UV sterilisation filter/pump were also used to treat the effluent exiting the WSF to reduce the bacterial content of the recycled waste water for re-use as wash water. Woodchip was included in the analysis at €20 per m^3 based on average industry costs with sand included at €15 per tonne and the lifetime of the woodchip and sand were estimated at 2 and 5 years respectively, (Ruane *et al.*, 2011). The average estimated cost of a UV filter pump capable of pumping 1000 m^3 $year^{-1}$ was €2000, with an electricity usage of 1100 KWH year and the lifetime of the equipment was estimated at 8 years.

DSW model description: DSW economic assessment

The economic feasibility of the different options is based on differences in costs and/or differences in output. The management options investigated the use of alternative management strategies which create a number of potential cost differences or opportunities for increased production. The differences in costs were based on differences in the quantity of fertiliser used, water and DSW storage requirements, storage methods, spreading, and when the nutrients in DSW were taken into account, differences in the quantity of purchased fertiliser. The economic consequences for the savings obtained were based on current industry average fertiliser values, purchased water costs and DSW storage costs (Table 2). The value for increased production was based on the extra economic performance from a grass based dairy production system when extra herbage DM is grown and utilised within the system (Shalloo *et al.*, 2007). The nitrogen fertiliser replacement values (NFRV) of the nutrients contained in the DSW were based on findings of Minogue *et al.*, (2011, and 2012) (Table 3). The NFRV for the DSW mixed with

Table 3: Dairy soiled water (DSW) average nitrogen fertiliser replacement value (NFRV) and herbage DM response for Nitrogen (N) applied in spring, summer, autumn and winter applications

Application time	DSW NFRV%	Kg DM response to kg N
Spring	70	20
Summer	100	23
Autumn	50	10
Winter	50	5

Table 4: Management option 3 (MO3), in Nitrate regulations zones A, B, C and C1 prohibited application period and storage capacity required

Option	Nitrates zone	Prohibited Application period	Storage Capacity Required
MO3a[1]	A	15 October to 12 January	16 Weeks
MO3b[2]	B	15 October to 15 January	18 Weeks
MO3c[3]	C	15 October to 31 January	20 Weeks
MO3c1[4]	C1	15 October to 31 January	22 Weeks

[1]Management option 3a (MO3a).
[2]Management option 3b (MO3b).
[3]Management option 3c1 (MO3c).
[4]Management option 3c1 (MO3c1).

slurry was 40% (S.I. 610 2010). The DM response from the N applied in the DSW was based on the findings of Morrison *et al*. (1980).

Management options (MO) investigated

There were six management options investigated;

Option 1 (MO1), Comparison of DSW storage and application methods

In option MO1, an economic comparison and assessment of the different methods of DSW storage and methods of application of DSW were investigated. In this option, DSW is stored separately using CT, ST, and LT for the S.I. 610 (2010). Soiled water was stored for a minimum amount of time of (10 days) and applied all year round by application method VA, UA and IA. The annual average NFRV of 80% for DSW is used based on the findings of Minogue *et al*., (2012).

Option 2 (MO2), Comparison of DSW storage and recycling of water

In option MO2, the use of a WSF filter/treatment allows 80% of the DSW to be recycled as wash water. In this option, the untreated DSW is stored, for the S.I. 610 (2010) soiled water minimum amount of time, filtered through a WSF and 80% is recycled as yard wash water. The remaining DSW is applied all year round using the TA, UA and IA methods of application. In this option the same assumptions and storage methods are used in MO1.

Option MO3a–MOc1 (MO3a, MO3b, MO3c, MO3c1)

The effect of extended grazing practices on dairy soiled water storage in the nitrate regulations zone A, B, C and C1, with adequate on farm slurry storage.

Option MO3a, MO3b, MO3c, and MO3c1 investigate the implications of the prohibited application periods in different zones of the nitrate regulations (S.I. 610 2010),

Table 5: The economic consequences of management options MO1 to MO3 for different strategies for DSW with contrasting storage periods and methods of application for a spring calving dairy herd with 80 cows

Item	MO1[1]	MO2[2]	MO3a[3]	MO3b[4]	MO3c[5]	MO3c1[6]
Storage period (Days)	10	10	64	64	93	93
Quantity of DSW to be stored (m^3)	21	21	133	133	193	193
Storage costs CT[7]	€83	€83	€367	€321	€758	€758
Storage costs ST[8]	€38	€38	€170	€149	€351	€351
Storage costs LT[9]	€31	€31	€137	€120	€285	€285
Application costs TA[10]	€767	€153	€767	€767	€767	€767
Application costs UA[11]	€750	€750	€750	€750	€750	€750
Application costs IA[12]	€1043	€1009	€1034*	€1034*	€1030*	€1030*
Treatment costs WSF[13]	-	€1768	-	-	-	-
Frtiliser Nitrogen savings	€308	€20	€267	€267	€263	€263
Fertiliser Phosphorus savings	€108	€5	€93	€93	€92	€92
Fertiliser Potassium savings	€259	-	€194	€194	€186	€186
Water savings	-	€1523	-	-	-	-
Dry matter savings	€454	€37	€583	€583	€597	€597
Average net saving or (Cost)	€225	(€640)	(€214)	(€188)	(€466)	(€466)

[1]Management option 1 (MO1).
[2]Management option 2 (MO2).
[3]Management option 3a (MO3a).
[4]Management option 3b (MO3b).
[5]Management option 3c (MO3c).
[6]Management option 3c (MO3c1).
[7]Concrete tanks (CT).
[8]Circular slurry/effluent store (ST).
[9]Geomembrane lined lagoon (LT).
[10]Vacuum tanker (TA).
[11]Umbilical spreading system (UA).
[12]Farm waste water pump and irrigator system (IA).
[13]Woodchip filter and sand filter (WSF).
*DSW which was not mixed with slurry was applied using the IA method.

Table 6: Sensitivity analysis 2 (SA2), Fertiliser Nitrogen (N), Phosphorus (P), Potassium (K) and grazed herbage DM price increase

Item	Average value €/T
Calcium ammonium nitrate (CAN) 27.5%N	€ 370
Urea 46%N	€ 450
Super-phosphate (16% P)	€ 450
Muriate of potash 50% K	€490
Grazed herbage DM	€140

zones A, B, C and C1 respectively (Table 4). In this option, DSW produced during the prohibited application period of the different nitrate regulations zones A, B, C and C1, is allowed to mix with slurry during the closed period. The DSW is stored together with slurry for the maximum amount of time as specified for the respective zone A - C1 using the different storage types CT, ST and LT (Table 4). In this option, the economic consequences of extending the grazing season in relation to the costs associated with DSW storage and application method were investigated for the different nitrate regulations zones A, B, C and C1. The grazing season is extended until 01 December for zones A, B, C and C1, option MO3a, MO3b, MO3c, and MO3c1 respectively. The spring turnout date for zones A and B is extended to 17 February in MO3a and MO3b and spring turnout date for zones C and C1 is extended to the 17 March (MO3c and MO3c1). In this option, the farm system has the correct amount of slurry storage capacity required for nitrate regulations zone A - C1, and DSW is only applied to land during the spring, summer and autumn to maximise the agronomic benefits of the nutrients in the DSW.

Sensitivity analysis (SA)

Sensitivity analysis 1 (SA1)

In sensitivity analysis SA1, the effect of increased purchase price of water from €3 to €5 per m^3, was investigated.

Sensitivity analysis 2 (SA2)

The economic effects of increased fertiliser prices and increased value of DM were assessed. The price of N, P, K and DM were increased by a mean to 12, 6, 9 and 10% respectively (Table 5).

Sensitivity analysis 3A and 3B (SA3a, SA3b)

Sensitivity analyses SA3a and SA3b were undertaken to assess the economic effects of contractor application efficiency. This involved adjusting the average TA application rate from 45.5 to 36.6 m^3 per hour for SA3a and 54.5 m^3 per hour in SA3b.

3. Results

Storage period and quantity of DSW stored

In all options (MO1 to MO3) dairy herd size and land area remained the same, the storage period required for DSW ranged from 10 days to 93 days depending on the management option, resulting in the amount of storage required for the DSW produced to increase from 21 m^3 to 193 m^3 (Table 5). Option MO1 and MO2 had the shortest storage period of 10 days and the smallest quantity of DSW storage of 21 m^3. In MO3a to MO3c1, storage period increased from 64 days to 93 days with the quantity of DSW storage increasing from 133 m^3 to 193 m^3 respectively (Table 6).

Storage costs

There was a large range of farm costs for the different methods of storage between options MO1 to MO3. Similarly as the quantity of DSW and storage period increased so too did the storage costs. In option MO1 and MO2, the total annual DSW storage costs for the farm were €83, €38 and €31 for CT, ST and LT respectively (Table 5). In MO3a to c1 the farm CT storage cost were €367, €321, €759 and €759 for MO3a, MO3b, MO3c, and MO3c1 respectively. The ST and LT storage cost were 54% and 63% less than the CT storage method for all options.

Application and Treatment costs

In options MO1 to MO3, the mean application costs for the different methods of application were €767 €750 and €1030 for TA, UA and IA respectively. The mean application costs per cow were €9.4, €9.6, €13.0 for the UB, TA and IA methods of application respectively.

Option MO2 had the lowest application costs of €153 using the TA method of application (Table 5). The low cost was due to the reduced quantity of DSW for application, as all DSW was filtered through a woodchip and sand filter. Using a WSF allowed 80% of the DSW to be recycled as wash water which reduced the quantity of DSW for application. The application costs for MO2 were €153, €750, €1008, for TA, UA and IA methods of application respectively. The treatment costs for using the WSF in MO2 were €1768. The total application costs for MO3a to MO3c1 were the same as MO1 using the TA and UA method of application. Using either combination of application method (TA+IA or UA+IA) for MO3, the application costs were increased by a mean of 95% for MO3a and MO3b and 99% MO3c and MO3c1 compared to only using the TA and UA method of application. The TA cost for applying the DSW mixed together with slurry produced during the closed periods was €161 for MO3a, and MO3b and €234 for MO3c and MO3c1 respectively. The IA cost for applying the DSW produced outside of the different zones closed periods was €1034 for MO3a, MO3b and €1030 for and MO3c and MO3c1 respectively (Table 5).

The UA application cost was 2% less than the TA method for applying all the DSW or DSW mixed together with slurry. However if the quantity to be applied was above the minimum quantity no surcharge would be incurred and the cost would be a further 7% less than the TA method. The IA method of application was the most expensive for all options.

Total costs

The average total costs for MO1 to MO3c1 were €1502, ranging from €904 to €2224 depending on the combination of storage application method and treatment used (Table 5).

Option MO1 and MO2 had the same storage costs, in MO2 the application costs using the TA method were approximately 80% less. However MO2 had the additional cost of the WSF, which was an additional 146% of total costs compared to MO1. Similarly in MO3a to MO3c1 total storage costs were higher than the other options investigated, due to the increased storage period. However in MO3, DSW was stored for the entire closed period utilising the on farm slurry storage and the total storage costs were reduced by 31%, 40%, 2% and 2% for MO3a, MO3b, MO3c and MO3c1 respectively compared to if separate storage had to be constructed. The results from the different management options investigated show that DSW storage cost had the biggest impact on the total costs, increasing the storage period and using a costly method of storage increased total costs. Application costs were similar across all management options investigated.

Total Savings

In each of the different options investigated there were potential savings (reduced expenditure) that could be achieved based on the different management options used for the DSW. The savings were in the form of fertiliser, water savings, and increased herbage DM production. In MO1 to MO3 the mean total savings for fertiliser were €482, ranging from €25 to €676, the fertiliser savings were comprised of savings made from N, P, and K (Table 5). As the storage period and management changed in MO3c and MO3c1 due to a later turnout date, the mean savings obtained from fertiliser reduced by approximately 2%. However there was a 2% increase in the savings obtained from extra DM in MO3c and MO3c1 compared to MO3c and MO3b. The mean total saving generated from extra DM produced for MO1 to MO3c1 was €475 ranging from lowest saving made of €37 for MO2 to the greatest saving made of €597 for MO3c to MO3c1 (Table 5). The average total savings for MO1–MO3 were €1211, ranging from €1129 to €1584. The greatest total saving of €1584 were made in MO2, as 80% of the DSW was recycled generating a saving of €1523 from the reduction in purchased water.

Net effect

When the total cost changes and savings associated with the different options investigated are added together, the result is described as the net effect. Within each of the different options, depending on the on the combination of storage type and application method, there was large variation in the net effect on profitability.

In MO1 the average farm net saving were €225, ranging from €3 to €348, for management options using the CT storage combined with the IA application method to LT storage method with the TA application method respectively (Table 5, Figure 1). In MO2, no net savings were obtained ranging from lowest net cost of €136 for the combined use of LT, TA and WSF, storage application and treatment methods. This is compared to the maximum net cost of €1043 using the combined storage application and treatment methods of CT, IA and WSF respectively.

In MO3 the net effect ranged from a mean cost of €333 to a mean net saving of €181 for the CT combined with IA and LT combined with UA methods of storage and application respectively.

In MO3c and MO3c1, as the storage period increased, the mean net effect reduced by an average of 132% to an average net cost of €466. The overall mean net savings for MO1 to MO3c1 ranged from €105 to €348 (Table 5, Figure 1). Regardless of options the greatest net saving were generated by using low cost storage facilities (LT) and the most economical method of application while maximising the nutrient content and DM response of the DSW.

Sensitivity analysis

Sensitivity analysis SA1

In sensitivity analyses SA1, as the purchase price of water increased, there was an extra saving of €1015. This allowed the total savings from using a WSF increase to €2599. In SA1 the net effect ranged from a net cost of €260 for CT x IA x WSF to a net saving of €646 for LT x TA x WSF (Table 7).

Sensitivity analysis SA2

In SA2, increasing the price for fertiliser N, P K and the value of DM resulted in a mean increase of 10% in total savings for all management options (Table 7).

Sensitivity analysis SA3a and SA3b

In SA3a, reducing the TA application rate to 36.6 m^3 per hour caused an increase of 25% in TA application costs. This resulted in the average net effect being reduced by a mean of 26%, ranging from 1% to 181% of a reduction for MO1 to MO3. In SA3b, increasing the TA application rate to 54.5^m per hour caused a reduction of 17% in TA costs. This resulted in the average net effect being increasing by a mean of 17%, ranging from 1% to 19% of a increase for MO1 to MO3c1 (Table 7).

4. Discussion

Irish Dairy Industry DSW management options

The current study simulates an Irish seasonal dairy production system in order to evaluate different strategies for efficient utilisation of DSW on dairy production systems in the Republic of Ireland. The simulation model focuses on evaluating the main factors and economic consequences of contrasting management options available for DSW. The financial consequences include, the costs associated with storage and application and the savings generated from reduced input usage and extra revenue from increased production. System simulation

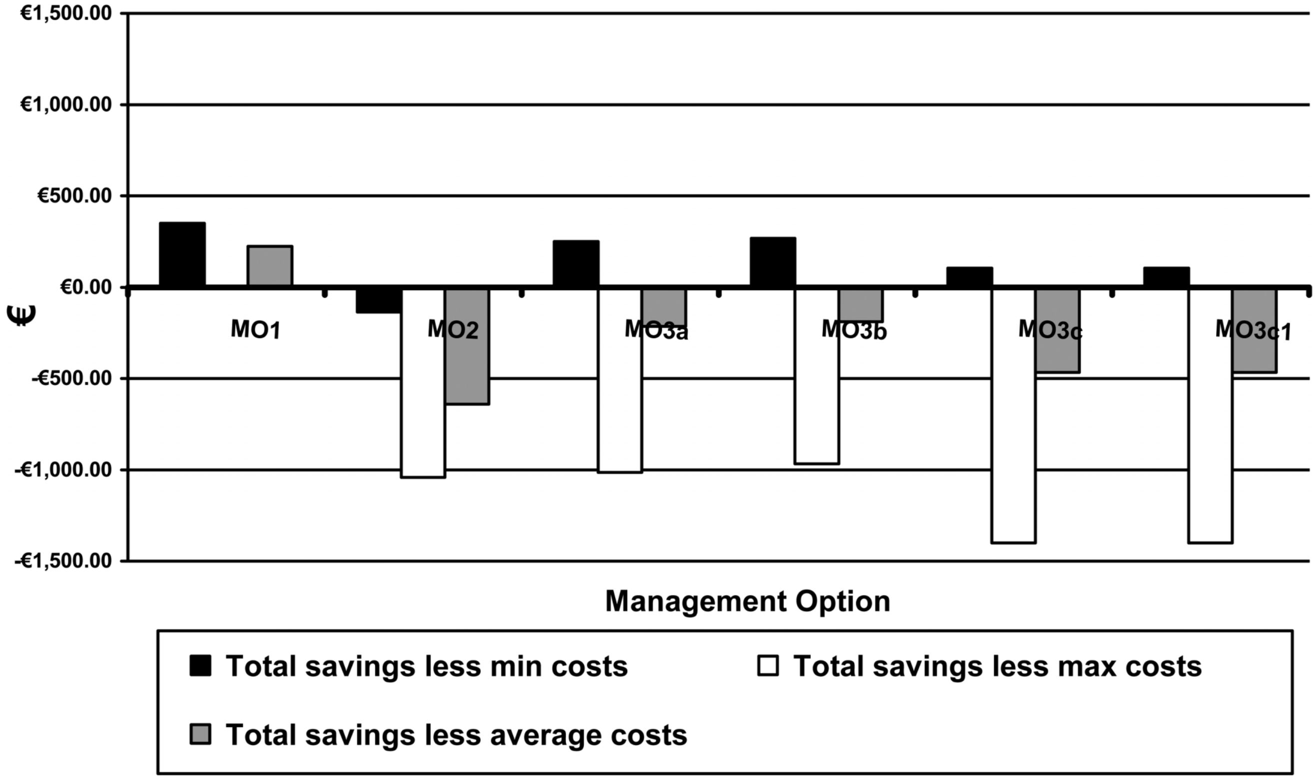

Figure 1: The minimum costs less total savings, maximum costs less total savings and average cost less total savings for management option MO1 to MO3c1

allows examination of alternative and contrasting production processes i.e. enterprise selection and resource allocation (Shalloo *et al.*, 2004) without having to experiment on a real system, which may be prohibitively costly, time-consuming or simply impractical (Ryan *et al.*, 2011).

Environmental legislation

In the Republic of Ireland, depending on the biological and nutrient content of DSW, it can be considered as soiled water or slurry (Minogue *et al.*, 2010; S.I. 610. 2010) which dictates the storage and application practices

Table 7: Sensitivity analysis showing the economic consequences of a range of different management strategies for DSW with contrasting storage periods and methods of application for a spring calving dairy herd with 80 cows

Item	MO1[1]	MO2[2]	MO3a[3]	MO3b[4]	MO3c[5]	MO3c1[6]
Application costs TA € for SA3a[7]	€959	€192	€959	€959	€959	€959
Application costs TA € for SA3b[8]	€640	€128	€640	€640	€640	€640
Frtiliser Nitrogen savings € for SA2[9]	€346	€22	€300	€300	€296	€296
Fertiliser Phosphourus savings € for SA2[10]	€114	€5	€99	€99	€98	€98
Fertiliser Potassium savings € for SA2[11]	€282	-	€206	€206	€197	€197
Water savings € for SA1[12]	-	€2538	-	-	-	-
Dry Matter savings € for SA2[13]	€500	€41	€642	€642	€658	€658
Average-marginal saving or cost € SA3a[14]	€161	(€885)	(€262)	(€236)	(€514)	(€514)
Average-marginal saving or cost € SA3b[15]	€267	(€864)	(€182)	(€156)	(€434)	(€434)

[1]Management option 1 (MO1).
[2]Management option 2 (MO2).
[3]Management option 3a (MO3a).
[4]Management option 3b (MO3b).
[5]Management option 3c (MO3c).
[6]Management option 3c1 (MO3c1).
[7]Application costs for vacuum tanker (TA) Sensitivity analysis 3a (SA3a).
[8]Application costs for vacuum tanker (TA) Sensitivity analysis 3b (SA3b).
[9]Frtiliser Nitrogen savings € for Sensitivity analysis 2 (SA2).
[10]Fertiliser Phosphourus savings € for Sensitivity analysis 2 (SA2).
[11]Fertiliser Potassium savings € Sensitivity analysis 2 (SA2).
[12]Water savings € for sensitivity analysis 1 (SA1).
[13]Dry Matter savings € sensitivity analysis 2(SA2).
[14]Average-marginal saving or cost € Sensitivity analysis 3a (SA3a).
[15]Average-marginal saving or cost Sensitivity analysis 3b (SA3b).

which can be undertaken. The nitrates directive (S.I. 610. 2010) sets a minimum winter waste storage and application period for animal wastes. The set waste storage period ranges from 10 days for soiled water to 22 weeks for slurry depending on the location within the country and storage specifications (zones A–C1) (S.I. 610. 2010). This can increase the storage costs by more than tenfold and have restrictions on the application window during the year (S.I. 610. 2010).

System simulation, comparison of DSW storage methods and costs

The main factor influencing total storage cost is the quantity of storage required, which is a reflection of the storage period, in the options investigated this ranged from 10 days to 93 days. Similarly, as the storage period increased from zone A to C1 (MO3a to MO3c1), the minimum storage quantity increased by 45% resulting in an increase in DSW storage costs. Minogue *et al*., (2010) found that the mean DSW storage period for separate DSW was 33 days on Irish dairy farms. The CT method of storage has been shown to be the most common method of slurry storage in Ireland (Hyde *et al*., 2006) and Europe (Menzi 2002) while Minogue *et al*., (2010) had similar findings for waste water storage. The options highlighted that storage was a major cost to the system accounting for nearly 50% of total DSW costs, with CT being the most costly form of storage. The most economical method of DSW storage was the LT, which was approximately 63% cheaper than the CT form of storage. The storage costs used in this study are based on average Irish industry prices. However as tank size increases, there will be additional savings/cost reductions due to the economics of scale (Ryan 2012).

In MO1, storing DSW for 10 days and applying all year round was the most economical management strategy for DSW. However this management strategy assumes the DSW nutrient content is below the limit set by the S.I 610.2010 for soiled water. However Minogue *et al*., (2010) found that approximately 13% of DSW samples were above the limit set by the S.I 610.2010 for soiled water, putting it into the category of slurry, which requires a longer storage period and restricted application times of the year.

Storing DSW together with slurry proved to be up to 45% more cost effective per m^3 stored than storing DSW separately. This management option assumes that the on-farm infrastructure allows DSW to be stored in the existing winter slurry storage; otherwise additional costs will be incurred. This emphasises the critical importance of careful planning and management practice evaluation to assess the most economical option suitable for the farm system.

Options MO3c and MO3c1 (zones C and C1) had an extra 30 days housing period, simulating a longer winter housing period. This is typically experienced in zones C and C1 or in areas with high rainfall and reduced soil trafficability. The additional storage period increased costs by over 30% and reduced the mean net effect by more than 60% compared to zone A and B. The additional cost in MO3c and MO3c1, highlight that producing milk during the housed period and delaying spring turnout date, incurs additional costs compared to milk that is produced during the grazing period. Patton *et al*., (2012) noted that selecting the ideal calving date and turnout date to suite the geographical location will significantly reduce production costs. Animal waste storage facilities are a major cost to a system, and extra costs due to the slurry storage requirements of the nitrates directive reduce profits of a system (Hennessy *et al*., 2005). In MO3, the on farm slurry storage facilities/infrastructure and their location in relation to the milking parlour will be a major factor influencing the storage costs associated with DSW.

Application and treatment costs and opportunities

The application costs were similar across options when no treatment processes are imposed. As the efficiency of application decreased or increased (SA3a, SA3b) additional costs or savings were experienced. In the simulation, the different application methods were not differentiated by any additional associated benefits. For example, the associated benefits of the UA and IA application method would be an increased opportunity for spring application and reduced soil compaction compared to the TA method (Lalor and Schulte 2008). In Ireland short winter housing and early spring turnout are key elements of low cost grass based production, however soil trafficability is the main restriction of spring grazing and application of animal wastes (Lalor and Schulte 2008) resulting in increased costs due to the weather and soil conditions (Brereton and Hope-Cawdrey 1988). However grass growth rate and nutrient uptake by grass is low when soils are very wet with increased risk of nutrient loss (Brereton and Hope-Cawdrey 1988). The IA application method was the most expensive due the capital investment of the pump and piping required for such a system, although there would be an advantage due to convenience associated with such a system, which is difficult to capture and simulate.

Using a WSF to treat the DSW, reduced application costs by 80%, increased savings by 40% and costs by over 150% and reduced over all net savings and profitability by nearly 400%. The use of a WSF reduced the quantity of purchased water for yard washing by 80% and reduced the quantity of N recycled by approximately 80%. The use of such a bio filtration system creates a synergistic opportunity from both an economically and environmentally perspective to reduce costs and reduce any potential nutrients lost (Ruane *et al*., 2010). However based on the current costs associated with using a WSF, there was no economical benefit for using a bio filtration system. Similarly other authors investigated alternative treatment process such as, constructed wetlands, (Dunne *et al*., 2005) as a treatment process to reduce application costs, with low running and maintenance costs, which are effective at reducing biological and nutrient concentrations from influent wastewaters. However they require a large area of land which adds an economic cost to such a process.

However, in the sensitivity analysis of increased water charges (SA1), the use of a WSF increased total savings increased by more than €1000 and the net effect was an average net saving/profitability of €375, which is a mean increase of 160%. This highlights how different technologies become cost effective as input prices increase.

In the current management options investigated, the UA and TA application methods were the most cost effective. However if the volume for application increased the UA method would be 9% more economical. Lalor, (2008) highlighting that, economic benefits of different application methods can be eroded due to high costs of the system or system inefficiencies. This emphasises matching the correct management practices to a system will maximise profit (Rotz *et al.*, 1999).

Nutrient utilisation and savings

Dairy soiled water contains valuable nutrients and used efficiently will generate cost savings from reduced chemical fertiliser use and increased herbage production (Schroder, 2005; Minogue *et al.*, 2010). The average quantity of nutrients recycled created a potential total saving of €470/farm or €12 per ha^{-1}. The nutrients recycled in the farm system have the potential to produce an additional 3500 kg of herbage DM (Morrison *et al.*, 1980). The extra DM produced would allow the dairy herd increase by one cow and generate a profit of ranging €300 to €700 depending on milk price (Patton *et al.*, 2012). In all options investigated, the best economic and agronomic savings were generated from additional DM grown during the spring and summer months from strategic applications of DSW (Minogue *et al.*, 2010). However, applying nutrients to land outside of the growing season, when there is little or no agronomic response or benefit is economically wasteful and potentially damaging to the environment (Jarvis and Aarts 2000).

In the Republic of Ireland, the average fertiliser N application rate is 168 kg N ha for dairy farms stocked at 2 Lu ha (Lalor *et al.*, 2011) accounting for approximately 9% of total costs (Hennessy *et al.*, 2010). Utilising DSW effectively can reduce N input by approx 6% creating a farm saving of approximately €400. The Irish dairy herd is projected to expand by 50% by 2020 (DAFF, 2010), which will be achieved through efficient utilisation of all available resources. Nitrogen fertiliser usage is estimated to increase by 17% (Donnellan *et al.*, 2012) and utilising the nutrients in DSW efficiently would allow approximately 33% of the estimated fertiliser N increased required to be achieved at no additional cost to the system.

Management option MO3 generated an average of 1% more savings and 24% extra DM produced compared to MO1, due to a strategic application of DSW in the spring and summer and autumn when NFRV and DM response to N are at their highest (Coulter and Lalor., 2008; Minogue *et al.*, 2010). The regulations of the nitrates directive are legally binding governing slurry storage and non-spreading periods, creating a distinct competitive advantage between the different zones A to C1 in the republic of Ireland. Similarly, all EU countries have to manage and utilise their resources and nutrients efficiently. The implementation of the Nitrates Directive has set limits on the quantity of organic N which can be produced per Ha with specific application periods based on weather, location and soil conditions (Humphreys *et al.*, 2012). Within the EU depending on how DSW is classified, dictates whether it is managed as soiled water or slurry, causing a 10 fold difference in management costs. Within different EU countries, the slurry storage period ranges from circa 3 months to 10 months depending on the location and local climatic conditions (91/676/EEC). This puts Ireland with a competitive advantage in relation to minimising system costs and maximising nutrient utilisation. However regardless of location, maximising the efficiency at which resources are utilised in grassland livestock production systems will ensure sustainable and economically viable food production (Peeters, 2009 2012). This emphasises the importance of minimising production system costs in situations where milk price and N price can be volatile (Humphreys *et al.*, 2012).

Dairy soiled water future management practices

Research in low cost facilities (Regan *et al.*, 2002) has shown there is huge potential in alternative low-capital-cost housing and effluent management facilities (Ruane *et al.*, 2010). A major advantage of such low-capital-cost facilities is that they enable farmers with limited resources to put in place facilities which will allow them to gain control over the consolidation or expansion of their business (Donnellan *et al.*, 2002; Scully *et al.*, 2002). For example, the CT capital cost for extra DSW storage was over 60% more costly compared to the low cost LT method of storage. Therefore with pressure to reduce costs and in the absence of grant-aid for larger farmers it is opportune to examine alternative lower cost systems (Dillon *et al.*, 2008). In the options investigated, regardless of how DSW is classified, storage and application were the main costs. As the method of storage and application changed, the costs associated with DSW increased by approximately 2 fold. Hence the importance of investigation management options fully before making a management decision that will have serious financial consequences (Rotz *et al.*, 1999; Shalloo *et al.*, 2004).

Management and optimising of DSW

Minimising costs, increasing resource utilisation and technical efficiency are fundamental essentials in operating a successful farm business (Finneran *et al.*, 2010). In MO3, as standard good grassland managed practice, extended autumn grazing (Hennessy *et al.*, 2006; Ryan *et al.*, 2010) was practiced with animals remaining at grass until 01 December. In these options, extending the grazing season reduced the quantity of slurry storage required or being utilised by up to 40% creating an opportunity for DSW to be stored in its place. Dairy soiled water only requires 44% of the storage space which is required for slurry for the same period of time, due to the reduced volume that is generated per day compared to slurry. Utilising the on farm resources in this way reduced the requirement for excessive DSW storage, creating an economic saving for the systems in MO3 while being fully in compliance with the nitrates directive. Combining the commencement of lactation with the start of grass growth and permitted application period (S.I. 610. 2010) minimised the quantity of DSW which would otherwise have to be stored for a long period of time.

In Europe, with the future abolishment of milk quotas, for dairy farmers to maintain their incomes, expansion and efficiency will require, incorporating tight cost control, particularly with capital investment (Dillon *et al*., 2008). Seasonal milk production systems economically outperform non seasonal milk production systems, due to the low costs associated with the system (Geary *et al*., 2013). Increasing the quantity of grazed grass in the diet of milk production systems has been proven to increase overall enterprise profits (Dillon *et al*., 2008). To maximise herbage consumed, the grazing season must be extended in autumn and spring, and grazing stocking rate must be maximised. Grass must be managed to allow for extended grazing, and the efficiency with which it is grown and utilised must be optimised (Ryan *et al*., 2009). Nitrogen is an essential nutrient required for grass growth and can be a potential limiting factor for optimum system performance (Ryan *et al*., 2010). In the present study, altering the grazing season length highlighted that regardless of storage type or method of application, in a spring calving dairy production system, the costs associated with DSW reduced as the length of time spent grazing increased. Minimising the level of investment in capital costs improves the long-term efficiency and competitiveness of the production system with more opportunities for expansion (Donnellan *et al*., 2011). However, the EU Nitrates Directive (Council of the European Communities, 1991), defines limits on N per hectare, and thus puts restrictions on the expansion of dairy production in intensive, specialised farms (Hennessy *et al*., 2005). A recent study by Lips and Rieder (2005) projected that quota abolition would allow production to move to areas of competitive advantage such as Denmark, Ireland and The Netherlands, predicting that milk production in Ireland could increase by up to 39%. In response to these policy changes and fluctuations in product prices, there will be a necessity for producers to increase scale, efficiency and competitiveness through improvements in breeding programs and better farm systems management practices (Dillon *et al*., 2008).

The finding of this study are similar to other countries within Europe, regardless of storage and application restrictions, the optimal management of dealing with livestock manures and dirty water will usually be to apply them to agricultural land at appropriate rates for the benefit of soil and the crop (Menzi 2002). Combining the commencement of lactation with the start of the grass growing season allowed the most economical options for effective DSW management. When combined with a nutrient management plan, the nutrients within the DSW will be used effectively to reduce fertiliser costs, maximise herbage production and reduce the risk of water pollution (DEFRA 2010).

5. Conclusion

The options investigated in this study highlight, combining the commencement of lactation with the start of grass growth and permitted animal manure application period, minimised the quantity of DSW which would otherwise have to be stored for a long period of time. Regardless of location or storage period, this proved to be the most economical option for effective DSW management. Dairy soiled water contains valuable nutrients and maximising nutrient utilisation while minimising loss to the environment will reduce input costs and increase the economic returns of the system. Reducing system costs and protecting the environment are fundamental for the long term development of sustainable dairy production systems. The findings from this study highlight that, within the Republic of Ireland, regardless of geographical location or storage period requirement, higher savings can be attained using low cost storage and application methods for DSW. Low cost storage and application methods are combined with strategic synchronisation between crop nutrient demand and supply, by applying DSW during the growing season for the greatest NFRV and herbage DM response. This emphasises the critical importance of the proper management of slurry and soiled water both in the interests of protecting the environment, maximizing nutrient value and reducing costs.

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CONFERENCE PAPER

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The impact of farm size on sustainability of dutch dairy farms

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ABSTRACT

Sustainable milk production systems require economically viable, environmentally sound and socially acceptable practices. This study compared the economic, environmental and societal impact of large-scale farms with other dairy farms in the Dutch Farm Accountancy Data Network (FADN). Moreover the integrated sustainable performance of large-scale dairy farms was explored. To quantify the impact of farm size on economic performance, we used net farm income (NFI), labour productivity and solvency. We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. To quantify societal performance, we used indicators on milk quality, cow lifetime and grazing hours.

Large-scale dairy farms had a higher labour productivity and NFI than other dairy farms, without compromising on phosphorus surplus, energy use or ghg emission. Higher profits were accompanied by a lower solvency ratio on large-scale farms. Pesticides use, however, was higher on large-scale dairy farms due to a lower share of grassland. Large-scale farms had a shorter cow lifetime and applied less grazing compared to other dairy farms.

For societal performance, current FADN does not have the potential to assess animal welfare using preferred animal-based indicators.

KEYWORDS: FADN; sustainability; effects of scale; dairy farming

1. Introduction

Since the introduction of milk quota by EU-regulation in 1984, the number of Dutch dairy farms decreased, maintaining an equal level of milk production on sector level, i.e. increased farm size. Increasing farm size is a continuing process in Dutch agricultural and horticultural sector (Van der Meulen *et al.*, 2011). To reduce fixed costs per kilogram of milk, further increase in farm size is necessary (Anonymous, 2009a). The abolishment of milk quota in the EU-27 by 2015, will further strengthen an increase in farm size and lead to a growth of Dutch milk production from 11.5 billion kg currently, up to 14 billion kg in 2020 (Anonymous, 2009a).

Sustainable milk production systems require economically viable, environmentally sound and socially acceptable practices (Thomassen *et al.*, 2009). Over the last decades, sustainable milk production became increasingly important (Anonymous, 2009b). The Dutch Dairy Association and the Dutch Organisation for Agriculture and Horticulture, therefore, joined forces in the Sustainable Dairy Chain initiative. Via the Sustainable Dairy Chain initiative, the processing industry and farmers aim to strengthen future support within the market and society (Reijs *et al.*, 2013).

In the Netherlands, perceptions on large-scale agriculture are diverse and trigger public discussion. Moreover, sustainable development of the production chain is included in policymaking increasingly (Boone and Dolman, 2010). Therefore, there is need for a clear view on the relation between farm size and sustainability impact. Several studies explored combined economic, environmental, and societal performance of animal production systems (Dolman *et al.*, 2012a; Meul *et al.*, 2008; Van Calker *et al.*, 2006). To our knowledge, however, no scientific publication exists that explored the impact of increasing farm size on integrated economic, environmental, and societal performance. The objective of this study, therefore, is to compare the economic, environmental and societal impact of large-scale farms with other dairy farms and explore the integrated sustainable performance of large-scale dairy farms.

2. Material and methods

We quantified economic, environmental and societal performance of specialized dairy farms in the Dutch Farm Accountancy Data Network (FADN) for 2011. The Agricultural Economics Research Institute

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continuously collects technical and economic data from a large sample of Dutch farms recorded in FADN, providing a wide range of economic, environmental and societal performance indicators. In 2011, FADN provided data from 298 dairy farms. To exclude effects of non-dairy activities, we selected dairy farms when at least 75% of the farm size, measured in standard output (SO), originated from dairy activity and data on all economic, environmental and societal performance indicators were available. Hence, we quantified the effect of farm size for 160 specialized dairy farms.

Performance indicators

Economic performance

To quantify the impact of farm size on economic performance, we quantified net farm income (NFI), labour productivity and solvency. NFI is often used as an indicator for profitability (Blank *et al*., 2009; Dekker *et al*., 2011; Van Calker *et al*., 2008). We defined NFI as the remuneration for management, family labour and capital that is left after all other costs are deducted (EC 2011). To correct for differences in farm size, we expressed NFI per unpaid annual working unit (awu). To give insight in the labour effort to realize the NFI, a measure of labour productivity is required (Dolman *et al*., 2012a). Labour productivity is a ratio of volume of output per unit of labour input (OECD, 2001). To enable a comparison of labour productivity among farms differing in scale, we expressed labour productivity in the average number of cows per annual working unit.

Solvency deals primarily with the firm's ability to meet total claims (Barry *et al*., 2000). A farm business is insolvent if sale of all assets fails to generate sufficient cash to pay all liabilities. We defined solvency as the ratio of total owners' equity as a per cent of total farm assets (equity-to-asset ratio) (Barry *et al*., 2000). The smaller the safety margins of equity, the greater the financial risk.

Environmental performance

We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. Two main environmental objectives within the Sustainable Dairy Chain initiative are decreasing non-renewable energy use and climate change per kg of milk produced and was therefore available within FADN. Dutch FADN recorded non-renewable energy use at farm level, while ghg emissions were derived from a cradle-to-farm-gate life cycle assessment (LCA) (Reijs *et al*., 2013). For policy evaluation purposes, FADN provided phosphorus surplus per hectare as a measure for eutrophication and pesticide use per hectare as a measure for eco-toxicity.

Societal performance

We quantified societal performance using indicators on milk quality, cow persistency and grazing. These societal indicators were included within the Sustainable Dairy Chain initiative and therefore available in FADN. As a measure of milk quality, we used the somatic cell count. High levels of somatic cell count relate to clinical and subclinical mastitis, which is the most important reason for early culling of dairy cows (Reijs *et al*., 2013). We quantified cow persistency using the average cow lifetime (years), from birth until culling. Extended average cow lifetime indicate improvement in animal health. The number of hours grazing is included as an indicator for animal welfare and social perception (Dolman *et al*., 2012b).

Integrated assessment

To explore the impact of farm size on integrated economic, environmental and societal performance we compared 15% (n=24) largest dairy farms by average number of cows with the rest of the group (n=136). Several studies described an approach to aggregate values of performance indicators of livestock systems into a total score on sustainability (Dolman *et al*., 2012a; Meul *et al*., 2008; Van Calker *et al*., 2006). We used an approach based on Meul *et al*. (2008) to compute the integrated performance on the ten economic, environmental and societal indicators. The performance was normalized on a scale from 0 through 100, whereby a score of 100 per indicator was assumed to be sustainable. Similar to *Meul et al*. (2008), a 10% and 90% percentile was used as a minimum and maximum value respectively. Using the 10^{th} and 90^{th} percentile tackles the problem of outliers in the linear approach. We visualized differences in integrated economic, environmental and societal performance using a benchmark diagram of the 15% largest dairy farms with the rest of the dairy farms. Differences between groups were tested using an independent sample t-test ($P<0.05$).

3. Results

Descriptive

The 15% large-scale dairy farms had a higher total milk production, a larger cultivated area and a higher number of cows ($P<0.001$) than other farms (Table 1). Moreover, large-scale dairy farms had a higher production per hectare ($P<0.001$) than other dairy farms, whereas milk production per cow was equal on both group of farms.

With 80% of total revenues origination from milk production, large-scale farms were more specialized than the rest of the farms. Furthermore, the percentage of grassland area was lower on large-scale farms ($P<0.05$) than other dairy farms.

Economic, environmental and societal performance

For economic performance, large-scale dairy farms realized a higher labour productivity and NFI per unpaid awu, whereas solvency (57%) was lower than on other farms ($P<0.01$) (Table 2, Figure 1). For environmental performance, pesticide use ($P<0.01$) was higher for large-scale farms. For societal performance, average cow lifetime ($P<0.05$) and grazing hours ($P<0.01$) were lower for large-scale dairy farms.

Table 1: Comparison between farm characteristics for large-scale farms and other specialized Dutch dairy farms in 2011 (FADN)

Farm characteristic	Large-scale	Other	Sig. a)
No. of farms	24	136	
Cows (#)	202	78	***
Total milk production (kg)	1,714,093	635,083	***
Cultivated area (ha)	94	48	***
Grassland (%)	76	83	*
Milk production per cow (kg)	8,500	8,143	ns
Milk production per ha (kg)	18,311	13,343	***
Milk revenues in total turnover (%)	80	77	*

a) *=P<0.05; **=P<0.01; ***=P<0.001; t-test: ns: not significant.

4. Discussion

Indicator selection

The basis for the selection of indicators was availability of data in the Dutch FADN and relevance within the Sustainable Dairy Chain initiative. For economic sustainability a large number of indicators are available to measure profitability. We choose NFI and labour productivity because other suggested attributes as liquidity are highly interrelated and linked to NFI (Van Calker *et al*., 2005).

We quantified environmental performance using indicators on non-renewable energy use, greenhouse gas (ghg) emissions, phosphorus surplus and pesticides use. For ghg we quantified cradle-to-farm-gate performance. Other indicators, however, quantified only impact at farm level and did not take into account the impact occurring in early stages of the milk production chain, such as purchased feed and fertilizers. Including indirect impact for energy use, eutrophication or acidification might differ for large-scale farms compared to other farms. Thomassen *et al*. (2009) stated, for example, that a high levels of milk production per ha positively effects total environmental impacts.

Van Calker *et al*. (2005) divided societal sustainability in internal and external societal sustainability. Internal societal sustainability represents the farmers' and employees working conditions, whereas external sustainability includes the societal concern about the impact of agriculture on the wellbeing of animals and people, such as animal welfare, food quality and spatial quality. FADN did not offer the possibility to quantify indicators for the farmers and employers working conditions. External societal performance of farms could be quantified based on FADN using somatic cell count, cow lifetime and grazing hours. We acknowledge that pasture hours is a simple indicator for welfare. Large dairy farms keep cows in the cowshed frequently. The modernity of cowsheds is higher on large dairy farms (Van der Meulen *et al*., 2011). In this analysis no indicator was available for the relationship between animal welfare and housing systems. Current FADN does not have the potential to assess animal welfare using preferred animal-based indicators. We didn't report about one relevant societal issue, food safety. The use of antibiotics is a suitable indicator for food safety (Dolman *et al*., 2012a). The use of antibiotics (daily dosages per animal year) is not reported, due to a lack of observations. Besides animal welfare and food quality, external sustainability includes spatial planning problems to cover the minimal aspects of societal performance. The effect on spatial quality is not quantifiable on farm level, and therefore, not included in the FADN sample (Dolman *et al*., 2012a).

Table 2: Economic, environmental and societal performance of large-scale and other specialized Dutch dairy farms in 2011 (FADN)

	Large-scale	Other	Sig. a)
Economic			
Labour productivity (cow/awu) b)	80	49	***
Net farm income (euro/unpaid awu)	72,840	31,368	***
Solvency (%)	57	70	***
Environmental			
Energy use (MJ/kg)	0.6	0.6	ns
Ghg emissions (kg CO_2-eq./kg) c)	1.2	1.3	ns
Phosphorus surplus (kg/ha)	5	14	ns
Pesticides use (kg as/ha) d)	1.2	0.5	**
Societal			
Somatic cell count (average/year)	210	216	ns
Cow lifetime (years)	4.8	5.4	*
Grazing hours (hours/cow/day)	1	8	***

a) *=P<0.05; **=P<0.01; ***=P<0.001; t-test: ns: not significant;
b) awu: annual working unit;
c) cradle-to-farm-gate greenhouse gas (Ghg) emissions;
d) as: active substance.

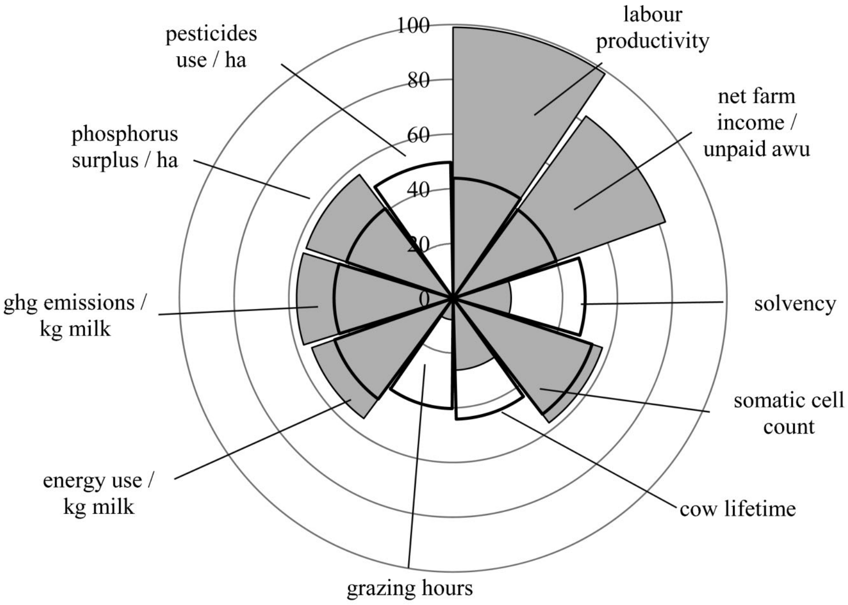

Figure 1: Comparison of indicator scores, 0 (not sustainable) and 100 (sustainable) of large-scale farms (grey wedges) with other specialized Dutch dairy farms in 2011 (FADN) (thick black line)

Economic, environmental and societal performance

We used most recent available FADN data from one year, i.e. 2011. There were large fluctuations in NFI between years, which may affect the outcome of our analyses. The year 2011 was a relatively prosperous year, with a high milk price (Van der Meulen *et al.*, 2012). In a year with a low milk price, milk revenue and incomes will decline and significant differences on profitability caused by large-scale would be less.

Better economic results were accompanied by greater financial risks, i.e. lower equity-to-asset ratio. Large-scale farms had a lower solvency than other farms. The increased scale was mainly financed with bank loans. Higher funding makes large-scale farms vulnerable to price fluctuations in the future. The critical issue relating to solvency is the ability of the farm to generate cash to meet all expenses and service the debt with an acceptable margin of safety. Solvency ratios do not indicate an optimal level of leverage for a firm (Barry *et al.*, 2000). Many farm lenders prefer borrowers having at least as much investment in their own farm as their lenders do. Therefore, a standard rule of thumb for the minimum solvency-ratio is 50%. However, the solvency norm varies substantially among farm business and from one type to another. It is commonly accepted that larger farms can carry relatively greater debt loads (Barry *et al.*, 2000).

For environmental performance, we observed only a higher pesticides use on large-scale farms. Large-scale dairy farms had a lower share of grassland than other dairy farms. On large-scale dairy farms, grassland is more frequently rotated with maize resulting in a higher pesticides use compared with other dairy farms.

Large-scale dairy farms had an earlier culling age than other dairy farms. The high number of cows per awu, resulting in less available time to take care of sick cows, might cause this. Another explanation might be that large-scale dairy farms applied a lower grazing frequency than other dairy farms. Grazing becomes more complicated with increasing herd size. Higher levels of grazing decrease leg and claw problems for housing systems with non-optimal housing systems (Van den Pol-van Dasselaar *et al.*, 2008).

5. Conclusion

Large-scale dairy farms had a higher labour productivity and NFI than other dairy farms, without compromising on phosphorus surplus, energy use or ghg emission. Higher profits were accompanied by a lower solvency ratio on large-scale farms. Pesticides use, however, was higher on large-scale dairy farms due to a lower share of grassland. Large-scale farms had a shorter cow lifetime and applied less grazing compared to other dairy farms.

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BOOK REVIEW

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Farm management extension guides

David Kahan

Six books, published 2013 by Food and Agriculture Organization of the United Nations, Rome. Published as pdf e-books, free of charge.

1. Market-oriented farming: an overview. E-ISBN 978-92-5-107540-1. 90pp. http://www.fao.org/docrep/018/i3227e/i3227e.pdf
2. Economics for farm management extension. E-ISBN 978-92-5-107542-5. 90pp. http://www.fao.org/docrep/018/i3228e/i3228e.pdf
3. Managing risk in farming. 107pp. E-ISBN 978-92-5-107544-9 http://www.fao.org/docrep/018/i3229e/i3229e.pdf (First printed 2008)
4. Farm business analysis using benchmarking. 142pp. E-ISBN 978-92-5-107546-3 http://www.fao.org/docrep/018/i3230e/i3230e.pdf
5. Entrepreneurship in farming. 127pp. E-ISBN 978-92-5-107548-7. http://www.fao.org/docrep/018/i3231e/i3231e.pdf
6. The role of the farm management specialist in extension. 127pp. E-ISBN 978-92-5-107552-4. http://www.fao.org/docrep/018/i3232e/i3232e.pdf

Perhaps the only subject around which some consensus has been built within the development community about the appropriate path to develop smallholder farming is market access, which invariably implies commercializing peasant agriculture and producing beyond mere subsistence needs. The argument is constantly turning to the logic of generating a surplus which can be sold for profit as the sure way to alleviate poverty. After all, if cash income is the one universally agreed measure of well-being, the opportunity to earn it must be a central goal of policy to improve livelihoods. The academic literature has also given a significant amount of attention to the notion of market participation of small farmers. But market participation presupposes that output expands sufficiently for the farmer to sell the surplus while meeting the household's needs. This seems a tall order where output has been on the decline for a long time and prospects of small farmers making a smooth transition from their existing 'keyhole gardening' to market-oriented farming, have been remote.

Expanding output and productivity of small farms must therefore become a priority. But the specific ways and means to achieve these have hardly been explored beyond the generalist prescriptions for government to formulate policies to support small farmers. The theoretical foundations of such prescriptions have not always been rigorously examined and explicated, nor has adequate attention been given to the imperative for more practical interventions at the level of production and utilization of produce, procurement and use of inputs, pricing of inputs and outputs, and the arrangements that mediate and facilitate these processes. This yawning gap seems to be what the 6-volume series published by the Food and Agriculture Organization of the United Nations (FAO) set out to achieve.

The six volumes have been appropriately entitled:

1. Market-oriented farming: an overview
2. Economics for farm management extension
3. Managing risk in farming
4. Farm business analysis using benchmarking
5. Entrepreneurship in farming
6. The role of the farm management specialist in extension

The single author of these volumes, David Kahan, justifies the production of these documents on the grounds that they focus on the capacitation of the small farmers. The current era that features rapid population growth, urbanization, and market liberalization has altered the competitive terrain in which small farmers find themselves and call for urgent action to focus on empowerment to strengthen production capabilities through building up management skills and competencies necessary to confront the emerging challenges. It is recognized that the challenge goes beyond confronting challenges to making farming pay its way through enlarged profitability. The agricultural extension system was seen as the source of this empowerment and its own capacitation in that direction is crucial. The crucial challenge is responding in the most appropriate manner to the new needs that are associated with market-oriented agriculture. In order to effectively support and empower small farmers and transfer skills and capabilities to them, the extension service itself needs to be strengthened. This is what the series set out to achieve.

Taking the books in turn, the first one, *Market-oriented farming: an overview*, focuses on the changes in the character of developing country agriculture over the past decades. The global changes that now define the global development themes around which dialogues rage, have changed the scene in ways that are unmistakable and impactful. The book presents the current context in very simple and easily accessible language. In the first of the three chapters of the book, changes affecting farming are enunciated by drawing attention to the afore-mentioned global themes that included climate change, the information technology revolution that conspired with the trends towards greater market liberalization and globalization. The recent financial crises that came to a head in 2008 only exacerbated a problem that was already taking its toll in the unrelenting impoverishment and destitution of small farmers, and that was constituting a policy-making nightmare. Robust theoretical anchors for the mindset that commercialized agriculture held the key were presented in language that belies their immense sophistication and rigour.

The second book, *Economics for farm management extension*, dwells on the key concepts and principles of economics that both farmers and the farm support organizations, including the extension services, direly need. The whole question of farming as a business takes a different view of farmers and farming and incorporates pricing, for both inputs and outputs, and financial management that requires knowledge of basic economics. The functioning of a modern market economy needs to be clearly understood by everyone that operates in it and those basic economic concepts and principles were crucial to understanding such an economy.

The third book, *Managing Risk in Farming*, deals with the question of risks in agriculture which no doubt constitute the most potent and formidable obstacle to investment in the first instance. If farmers are reluctant to invest due to their perception of risks with which they could not cope, then the prospects for profitability were very remote. The book provides the extension services with tools to identify and recognize the nature of risks and how to deal with them. The essential management practices needed to confront these issues and deal with them decisively are highlighted in this volume.

The fourth book, *Farm business analysis using benchmarking*, addresses the aspects that prepared the farmer to see and operate farming as a business, rather than as a juxtaposition of cultural and economic and subsistence undertaking whose central goal was to attend to households' survival. Market-orientation embodied in the view of farming as a business implied expanded output that is essential to food security. How farmers can monitor their farming operations in terms of costs and returns is explained in the book. Benchmarking as a tool for planning the farm investment programme is illustrated and the steps in comparing entities with successful schemes in related geographical and socio-economic contexts are enunciated.

The fifth book, *Entrepreneurship in farming*, is one that explores the crucial role of entrepreneurial spirit and entrepreneurship in mediating farm activities and the emergence of farming as a business. Understanding this concept and how it influences the generation of farm surpluses and stimulates economic activity is the focus of the book which also explores its theoretical foundations and applications in the real life. Importantly, the book takes the reader through the steps for developing entrepreneurship and how the extension service can contribute in that process.

The sixth book, *The role of the farm management specialist in extension*, addresses what is easily the most crucial topic from the point of view of developing the capacity to transform the agricultural system. The extension system should be in a position to impart the required management skills and competencies to the clientele it serves. This required that it acquires these skills itself and possesses the necessary systems and procedures to transfer these skills in a way that is empowering and fits the adult learning context involved in training of farmers. This final book turns attention to awareness creation about what farm management skills are mandatory and the organizational requirements to deliver these.

The series publisher makes the very modest claim that it was written with the extension services in mind. However, the series contains quite robust and elegant intellectual messages,transmitted with simple sophistication that makes them accessible and appealing to all and sundry. Fundamental courses in agricultural marketing and development will benefit from the definitions and explanations the book provides of complex terms that are rendered in language that makes them clearer. Academic minded persons and policy makers will definitely find something for them in these series.

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VIEWPOINT

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Treasuring trees for agricultural management transformation

E. JOHN WIBBERLEY[1]

ABSTRACT

Trees are vital to earth's ecosystem. In many places, loss of trees is faster than their replacement. With particular reference to sub-Saharan Africa, this paper seeks to review in outline the value of trees in order to encourage better understanding, appreciation and practical management response. A treasury is a store of wealth, a treasurer its custodian, and the act of treasuring is a positive response to the value of that wealth. Trees are a multi-faceted source of wealth. Not just foresters and forest communities but especially farmers, and also civil societies, families and individuals at large need to care about and for trees. The paper briefly indicates the global status of forests, their ecological and economic significance, and proposes tree-treasuring strategies and practices together with their integration in agro-ecological systems for global food security. While recognising the excellent work that is being done in some places, it is a wider call for deeper appreciation and fresh endeavours concerning trees and their integral management within farming systems. The paper also reports responses to practical field workshops on trees held in Malawi in 2012. In short, integration of trees is deemed essential for sustainable agriculture within ecosystem security.

KEYWORDS: trees; agro-ecological; ecosystem security; integral; management; extension

1. Introduction

Forests cover some 3.9 billion hectares (9.6 billion acres) which is approximately 30% of the world's land surface. FAO (2012) estimates that around 13 million hectares of forests were converted to other uses or lost through natural causes annually between 2000 and 2010. Their estimated annual rate of forest area increase was 5 million hectares. Globally, the highest proportion of land under forest is in the tiny African nation of Gabon. Rwanda scored the highest global rate of forestation during the decade 2000–10, with around +6.5% per annum, while within Africa, Zambia had the greatest proportion of its land area under national protection (some 41%). In Africa, the largest concentration of forest is found in the Congo basin covering some 1.3 million km^2. On the other hand, the fastest rates of deforestation recorded globally during 2000–2010 were in Africa: Burundi (5.5%); Togo (4.7%); Nigeria (3.5%). The challenge for Africa is clear (Maathai, 2009) with much of countries like Malawi largely deforested with farmland and 'mango-savannah' instead, owing especially to huge woodfuel demands of the rising population. Informal surveys by the author of some 350 families in rural Malawi in 2006 indicated that the average family spent 30–35% of disposable monthly income on acquiring woodfuel, most of it burnt wastefully to cook on 3 large stones.

FAO (2011) notes:-

- Forests are home to 300 million people worldwide, formally employing 14 M.
- More than 1.6 billion people depend to varying degrees on forests for their livelihoods, e.g. fuelwood, medicinal plants and forest foods.
- About 60 million indigenous people are almost wholly dependent on forests.
- Some 350 million people who live within or adjacent to dense forests depend on them to a high degree for subsistence and income.
- In developing countries, about 1.2 billion people rely on agroforestry farming systems that help to sustain agricultural productivity and generate income.
- Mangrove forests, which cover about 15 million hectares worldwide, are essential to the life cycles of the majority of the world's commercial fish species.

2. Treasure

Trees should be valued at various levels (Figure 1) - intrinsically as God's creation, as notable specimens and as landscape features, for their products, for their protection and for their global ecosystem role. Trees are treasured by some as ethical investments, where *Ethical Forestry* (www.ethicalforestry.com) cites a *Moneyweek* claim 'forestry is the only asset class in existence that has risen in three out of the four market collapses of the 20th century'. Timber is uncorrelated to stock markets with almost sixfold investment growth projected over 12 years. Above all, trees are integral to ecosystem security, which refers to the total provision from land of food,

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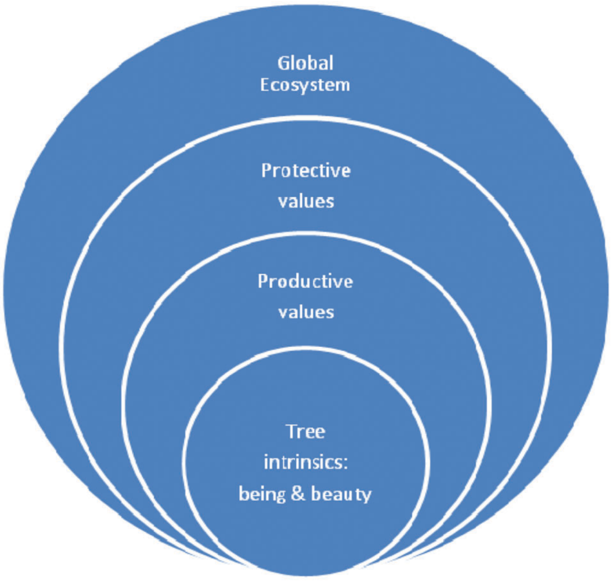

Figure 1: Levels of Values to Treasure in Trees

water, energy, carbon sequestration and cultural services. The world's army of farmers is at the forefront of integral management for ecosystem security and they must retain control of their own seeds, crop rotations, trees, livestock and practical land husbandry to enable them to value, improve and sustain this management.

FAO's 9th biennial issue of *State of the World's Forests* (FAO 2011), published at the outset of 2011, the International Year of Forests, considers the theme 'Changing pathways, changing lives: forests as multiple pathways to sustainable development'. It takes a holistic view of the multiple ways in which forests support livelihoods and should be valued. Chapters highlight four key areas that warrant greater attention: regional trends on forest resources; the development of sustainable forest industries; climate change mitigation and adaptation; and the local value of forests. Considered together, these themes provide insights on the true contribution of forests to the creation of sustainable livelihoods and alleviation of poverty. Global forest cover (Table 1) is 93% natural, 7% planted.

The 'Great Green Wall' of trees proposed in 2012 by Dennis Garrity of World Agroforestry Centre (formerly ICRAF; www.worldagroforestry.org) will extend from the Senegalese coast to the Djibouti coast upon completion. It can be achieved when practices such as Evergreen Agriculture are used against desertification because its affordable, sustainable and accessible farming methods benefit not only rural smallholder farmers but also the environment, encouraging agro-ecological farming systems among the world's around 500 million farm families (Wibberley and Turner, 2012) - with integration of trees as key to ecosystem security.

To treasure trees, one needs to appreciate something of the rich international diversity of species (Dalziel, J.M., 1937; Hora, 1981; Van Wyk and Van Wyk, 1997; Fay and Nichols, 2009), current realities (CFA, 2010; FAO, 2012) and the history of forests–at least in one's own country (Hinde, 1985; Collett, 1993). For instance, the evergreen red mahogany or *mbawa* (*Khaya anthotheca = K.nyassica*) is fittingly the national tree of Malawi. Also among Malawi's special trees is *Aleurites montana* (of *Euphorbiaceae*) introduced in 1931 as a source of tung oil exported for paints and varnishes. A splendid allegory of the value of tree planting has been published, republished and dramatised since it first appeared (Giono, 1954). The spiritual significance of trees perhaps relates in part to the fact that many of them and their associated forests far transcend the span of a human life. There are baobabs in Africa and olive trees in the Garden of Gethsemane in Jerusalem known to exceed 3,000 years of age.

There is considerable Biblical reference to trees, including several named species, and lessons drawn from them, from which we can derive both spiritual and physical lessons to apply to our lives, land and livelihoods. In the book of Revelation, of all creatures, trees are singled out for protection alongside land and sea (Rev.7:3). In the final chapter of the Bible is the vision of the tree of life bearing twelve fruits in season and having leaves for the 'healing of the nations' (Rev.22:2;14). Substantial healing now is possible using knowledge of the healing properties of various trees (see www.anamed.org). Reasons for growing and nurturing trees are manifold (Wood and Burley, 1991). They can both help halt desertification and also reclaim degraded land. Key productive and protective values of trees are depicted in Figure 2.

3. Resources

The connection between forests, food and people has long been understood (Beresford-Peirse, 1968). Astill (2010) incorporated global climatic considerations into the picture. As cities expand, trees disappear. This is very evident on mountains adjoining Freetown, Sierra Leone.

As for timber, the world's largest exporters are Canada, Sweden and Finland, while by far the largest imports of timber go to China (protecting its own 22% forest cover), followed by Japan (despite its 68% forest

Table 1: Global Forest Cover 2010

PLACE	FOREST Mha	TOTAL LAND Mha	Forest as% total land
Africa	**674**	**2974**	**23**
Asia	593	3091	19
All Europe	1005	2215	45
N&C America	705	2135	33
S. America	864	1746	49
Oceania	191	849	23
WORLD	**4033**	**13011**	**31**

Source: www.forestry.gov.uk/statistics 2011.

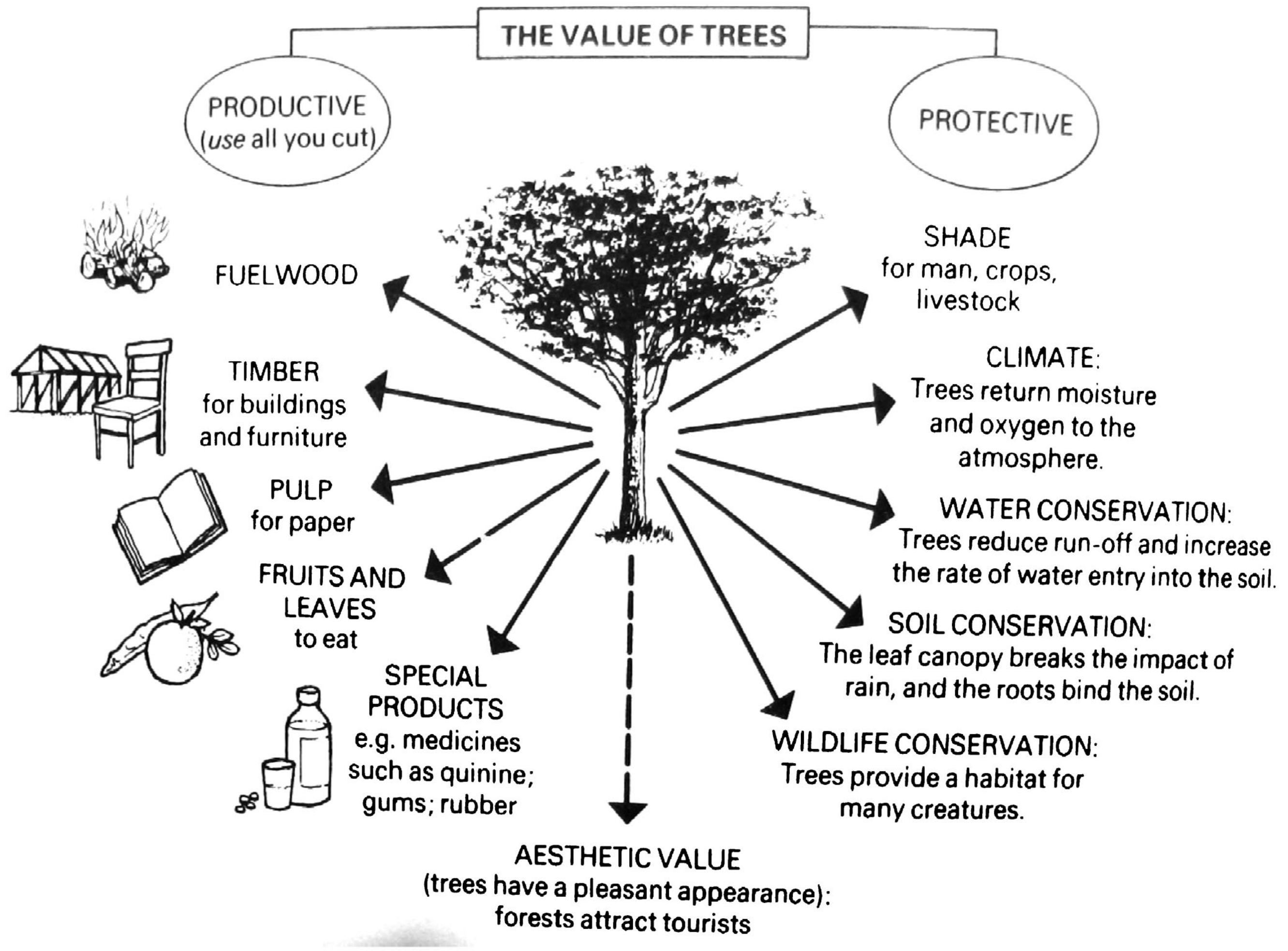

Figure 2: The Value of Trees. Source: Joy and Wibberley (1979). Note omission then of 'carbon sequestration' linked to climate - a more recent emphasis

cover) and the UK. Concerning forest loss, African wood removal (Mm^3) totals 712 and is 13.5% of the World's 5259. However, 85–90% of this removal in Africa is as woodfuel while the world average removal as woodfuel is 35% of all. Global Forest Area losses during 1990–2010 were just over 13 Mha (down 0.33%). In Africa, losses were almost 7.5 Mha; S. America was 8.2 Mha down. On the other hand, while Asia lost almost 0.6 Mha from 1990–2000, it gained 2.2 Mha between 2000 and 2010 (FAO, 2012). Encouragingly too, global designation of forest land for biodiversity conservation increased by 35% to occupy 12% of the world's forests in those two decades.

4. Ecology

Humans are an integral part of forest and rural communities. However, indigenous and local communities of Gambella, Ethiopia - 70,000 people in all - are being forcibly relocated to make land available for investment in agriculture. There are plans to relocate an additional 150,000 people, most of whom are subsistence farmers who have been able, until now, to feed their families without receiving government or foreign aid over the last twenty years. (Wibberley, 2011).

Created in 1959, the African Forestry Wildlife Commission (AFWC) is one of six Regional Forestry Commissions established by FAO to provide a policy and technical forum for countries to discuss and address forest issues on a regional basis. It meets every two years. Nasi and van Vliet (2011) have measured wildlife populations in logging concessions in central Africa in order to monitor and evaluate their biodiversity impacts. The Nyika-Vwaza Trust affords habitat and wildlife protection not only within Malawi but across the border into Zambia. National organisations play a vital role, such as the Wildlife and Environmental Society of Malawi (WESM), as do civil society organisations that have become transnational such as the Green Belt Movement begun in 1977 in Kenya by the late Wangari Maathai (2006; 2007) – though she began with her own small tree nursery in 1974. Engaging local farmers and their management skills is absolutely key.

5. Extension

The principles for extension of tree planting adopted and field tested for four decades by the Green Belt Movement (GBM; Maathai, 2006) are listed in Table 2. GBM bases its work on the following values: love for environment conservation; self and community empowerment; volunteerism; strong sense of belonging to a community of like-minded people;

Table 2: The Ten-Step GBM Procedure for adoption of Tree-Planting

1.	Dissemination of information to communities on tree-planting importance;
2.	Facilitation of Group formation in communities;
3.	Registration of Groups with GBM HQ;
4.	Preparation of Tree Nursery sites by Groups;
5.	Reporting monthly by Groups to GBM HQ;
6.	Announcement by Groups to communities:-'seedlings ready', inviting interest to dig holes;
7.	Checking of tree holes by Group members;
8.	Issuing of tree seedlings to those who dug holes properly;
9.	Verification of tree seedling survival by Group members, reporting to GBM HQ;
10.	Second verification of seedling survival, and purchase of seedlings by GBM if successful.

Source: Maathai, 2006.

accountability, transparency, honesty. Groups are crucial (Kyamuwendo and Wibberley, 2011).

From the outset, the GBM tree-planting campaign was linked to food security and water harvesting at household level, civic education, advocacy, Green Belt safaris to gain inspiration from elsewhere, and Pan-African training workshops. Kenya has been well-supplied with information to help appropriate tree-planting there (Teel, 1984; Gammell, 1989). However, GBM results have been spectacular, with well over 30 million trees planted in Kenya alone - a triumph of rural forestation and reforestation. Rural employment has been created and environmental awareness raised. Individuals and communities have been inspired, empowered and mobilised. Biodiversity, a wider range of food crops and water catchments have been protected locally.

Women have risen in status through their practice, associated increase in availability of agricultural tools, advocacy and networking via GBM. All this has led to extensive documentation and recognition of GBM internationally. Lessons learned by GBM include: - community felt needs must be addressed; participants must perceive the sense of this work; good leadership is vital; community motivation requires patience and commitment; short-term incentives help poor people to engage with it; both decision-makers and communities need to be reached simultaneously; GBM field staff must be keen observers; communities must understand the project objectives and own it; limited resources demand prioritisation; democratic administration and management is key. The Mission of GBM is 'to mobilise community consciousness for self-determination, equity, improved livelihood securities and environmental conservation using trees as the entry point' (Maathai, 2006).

There are constraints in promoting tree-planting, such as the taboos on fruit tree planting in northern Ghana where some fear they will die once the trees planted start fruiting. However, there is real pride in tree planting too such that people will hardly destroy trees they have planted themselves. During long dry seasons, many fodder trees are browsed by livestock but few people plant them. Hay for dry season livestock feeding can be made from the foliage of a number of trees including *Bauhinia* species (Neats-foot in RSA) and a range of mulberry trees (*Morus spp*.). There is a range of tropical leguminous trees and shrubs *Leucaena spp., Gliricidia spp.* ('Mother of Cocoa'), pigeon pea (*Cajanus cajan*) used for alley cropping. *Calliandra calothyrsus* is an excellent fodder tree candidate and also attracts bees for bee-keeping microenterprises (van Houten, 1998; Wambugu, 2002). The challenge is to scale up the use of such species (Wambugu *et al.*, 2001). All steps to plant more trees merit consideration since too many households depend on selling charcoal thus further depleting existing tree cover. Adoption of fuel-saving stoves (www.fourthway.co.uk) needs to go alongside tree-planting. These can save as much as 70% of woodfuel compared with typical cooking on three stones.

6. Systems

An agro-ecological approach in which trees, field crops and livestock are integrated is vital for the secure future of farming systems, and for their sustainable intensification (Koohafkan *et al.*, 2011; Wibberley and Turner, 2012). It has long been known that forest resources can improve agriculture (Adeyoju, 1975). Lack of trees leads to farmers using their maize and other stalks as firewood instead of as mulch, which is crucial in conservation farming (Oldreive, 1993; Kassam, 2011). Agroforestry has been practised in various forms for many years in both tropical and temperate zones (Douglas and Hart, 1980; Barnard, 1990; Smith, Pearce and Wolfe, 2012). It has been especially advocated for dryland areas (Rocheleau *et al.*, 1988) and for soil conservation (Young, 1989; 2010). Carr (2002) charts the limited spread of agroforestry in Malawi, although it is part of the answer to greater soil degradation as population pressure increases in a context where most families lack capital for both yield-enhancing inputs such as fertilisers and for enough of their own animals to produce manures. *Faidherbia albida* is proving successful in Zambia, interplanted at 100 trees per hectare when it can fix up to 300 kg N/hectare (Aagaard, 2011). Its great advantage is that it sheds its leaves at the onset of rains to enrich the soil also removing their shading effect from the associated annual crop. Results can be spectacular with paradoxically greater crop growth under the trees than away from them! Furthermore, its pods and leaves are protein-rich for livestock feeding.

Secure tenure is an important prerequisite for sustainable forest management (Fortmann and Riddell, 1985). More diversified tenure systems could provide a basis for improving forest management and local livelihoods, particularly where the State has insufficient capacity to manage forests. In the past decade many countries have initiated efforts to reform their tenure arrangements for forests and forest land, devolving some degree of access and management from the State to others, mainly households, private companies and communities.

Table 3: FSC Certification, Rules and Guidance

Ten FSC Principles require the forest owner or manager to do the following:
1. Comply with all laws, regulations, treaties, conventions, agreements, & all FSC Criteria;
2. Define, document and legally establish long-term tenure and use rights;
3. Identify and uphold indigenous peoples' rights of ownership and use of land and resources;
4. Maintain or enhance forest workers' and local communities' socio-economic well-being;
5. Maintain or enhance long term economic, social & environmental benefits from the forest;
6. Maintain or restore the ecosystem, its biodiversity, resources and landscapes;
7. Have a management plan, implemented, monitored and documented;
8. Monitoring and assessing to demonstrate progress towards management objectives;
9. Maintain or enhance high conservation value forests & attributes which define such forests;
10. Plan and manage plantations in accordance with FSC Principles and Criteria.

The Forest Stewardship Council (FSC) website (https://ic.fsc.org/) informs us that it "is a global, not-for-profit organisation dedicated to the promotion of responsible forest management worldwide, founded in California in 1990." FSC enables businesses and consumers to make informed choices about the forest products they buy, and creates positive change by engaging the power of market dynamics. FSC facilitates the development of standards, ensures monitoring of certified operations and protects the FSC trademark so consumers can choose products that come from well managed forests. Members include some of the world's leading environmental NGOs (e.g. WWF), businesses (*Tetra Pak* and *Mondi* plc) and social organisations (e.g. The National Aboriginal Forestry Association of Canada), as well as forest owners and managers, processing companies and campaigners, and individuals. Together these diverse voices define best practices for forestry to address social and environmental issues. The membership consensus sets the FSC Principles and Criteria - the highest standards of forest management which are environmentally appropriate, socially beneficial and economically viable (Table 3). This diversity is FSC's strength and to make sure no one viewpoint dominates the others, its membership has three chambers–environmental, social and economic–that have equal voices in decision-making, with both global North and South sub-chambers. Rainforest desperately needs protection internationally (McMahon, 2009) including Africa's Congo Basin treasury (Maathai, 2009).

Environmentally appropriate forest management ensures that the harvest of timber and non-timber products maintains the forest's biodiversity, productivity, and ecological processes. Socially beneficial forest management helps both local people and society at large to enjoy long-term benefits and also provides strong incentives to local people to sustain the forest resources and adhere to long-term management plans. Economically viable forest management means that forest operations are structured and managed so as to be sufficiently profitable, without generating financial profit at the expense of the forest resource, the ecosystem, or affected communities. The tension between the need to generate adequate financial returns and the principles of responsible forest operations can be reduced through efforts to market the full range of forest products and services for their best value.

7. Discussion

That trees and forests need management is beyond doubt (Blyth *et al.*, 1987). Plantations have their place (Evans, 1982) and coppicing can provide regular harvests (Macpherson, 1995). Community forestry can engage all ages of people both in new communal plantations and in managing indigenous ancient forests (Sjöholm, 1989). The human dimensions of deforestation need better understanding and action (Sponsel *et al.*, 1996; Scales, 2012). While forest protection is imperative as are reduced emissions from deforestation and desertification (REDD),

Table 4: Forest SWOT Analysis: some key points

STRENGTHS

- Productive–multiple and diverse products
- Protective–multiple benefits from local to global significance

WEAKNESSES

- Ties up land a long time, so softwood monocultures are too often planted
- Takes some years to reach maturity, especially in cooler areas

OPPORTUNITIES

- Integrated systems–agroforestry, silvo-pastoralism
- Adding value–high value items, tourism, ecosystem payments (REDD etc.)
- Investment for steady profit and environmental gain

THREATS

- Mechanised logging penetration rapidly and deeply into forests
- Cheap 'land grab' leases and sales to foreigners
- Deforestation for annual cropping or ranching feedlots

Table 5: Proposals for Tree and Forest Promotion

• Teach Bible heritage basis • Lift Environment awareness • Promote Tree Nurseries • Encourage 2-trees/house • Promote use of tree guards • Fuel-efficient stoves • Add value to forest produce	• Plant/retain riverbank trees • Promote Bee-keeping • Livestock control/housing • Best home & village competitions • Junior Conservation Clubs • Environment Care Groups • Churches as Demonstration points

exclusion of indigenous people from forests for the benefit of tourism and extractive business elites is a travesty. Long-term sustainable management and public enjoyment of forests cannot be attained unless indigenous populations and their livelihoods are recognised and mobilised to care (Ogana, 1990; Thomas and Wibberley, 2001). Those who

Table 6: Responses to Practical Tree Management Workshops, Malawi 2012

MCHIZANJALA ('Healing Hunger'): What have you learned/been reminded about? 18 attendees (60% male) • Trees in the Bible (14) • Caring for Trees (14) • Sustainability of Life • Uses of Trees (4) • Use of bamboo as water-pipe or gutter	**MCHIZANJALA**: What will you do in next 6 months? • Teach how to plant & start a Tree Nursery • Start a Tree Nursery & sell seedlings (2) • Plant trees on eroded/erodible land • Expand Conservation Farming • Use tree guards • Build a fuel-saving stove • Help form *FARMS* Groups • Raise chickens & use their manure to make compost & 'ring' trees against termites
KONGWE ('Cold'): What have you learned/been reminded about? 25 attendees (70% male) - 2 funerals • Why it is bad to destroy trees • Benefits and values of trees • Manure can also come from trees • Fuel-saving stoves • Importance of livestock care • Environment Care goes with spiritual life • Don't cultivate up to riverbanks • Raised livestock house can be home-made • *Leucaena* is animal feed (<25% ration) • Bees & Trees benefit each other • Avoid cows & goats eating plastic	**KONGWE**: What will you do in next 6 months? Plant trees: 10–25 each (12 people) • Plant 10 different kinds of tree • Establish a tree nursery (2) • Establish a Conservation Farming plot • Make a fuel-saving stove (5) • Teach how to make fuel saving stoves • Incorporate tree work in Farmers' Group
KASITU: What have you learned/been reminded about? 44 attendees (55% male, including 8 Chiefs) plus children & others • Uses of trees • How to care for trees • Goodness of fuel-saving stoves • God made us responsible to care • It is good to promote bee-keeping • Recommendations are possible to do • How to care for soil • Animal care and disease reduction	**KASITU**: What will you do in next 6 months? • Build proper housing for goats (7) • Start a tree nursery (20) • Do mulching and Conservation Farming (9) • Make a fuel-saving stove (9) • Establish a personal forest • Establish a Community Forest • Make tree guards (12) • Plant trees either side of the river (5) • Promote & start bee-keeping (20)–firstly in Kumi Lanjujhi village ('Ten Bees')
CHILEKA ('To leave'): What have you learned/been reminded about? 20 attendees (60% male); 2 funerals; • How to care for and protect trees • Spirit of working together • Agroforestry • Trees give us oxygen • How to care for animals • Trees give us food for all • Trees purify air of carbon dioxide • God wants us to care, not destroy creation • Managing trees and animals • Conservation farming • Benefits of fuel-saving stoves • Do not cultivate up to riverbanks	**CHILEKA**: What will you do in next 6 months? • Continue/expand conservation farming (7) • Plant 1 papaya and 1 mango (15) • Dry and preserve mangoes (6) • Make a fuel-saving stove (10) • Plant 20 trees (10 fruit/10 fodder) • Keep pigs in a proper pen • Share with existing farmer groups

plant their own trees tend to care for them. The work of the Green Belt Movement is an inspiration (Maathai, 2006). Key factors in the evaluation of afforestation are summarised by SWOT analysis (Strengths; Weaknesses; Opportunities; Threats) in Table 4.

8. Recommendations

Based on experience of rural community development and field extension work in Africa, it is proposed that fourteen points integrate to promote tree progress for sub-Saharan Africa and its sustainable agro-ecological framework (Table 5).

Responses following practical workshops facilitated by the author in four villages in Malawi in 2012 are shown in Table 6. Participants were asked to identify what they had learned or been reminded about during each workshop, with whom they would share this, and what they would do during the next six months with the resources that they control or influence. This is an approach followed internationally by the author with farmers over the past four decades at the conclusion of practical workshops.

9. Conclusions

Trees and forests, their planting and protection offer a unifying focus for sustainable rural development. Both locally and globally they link to communal well-being– the Biblical 'tree of life'. Reversal of the alarming scale of tree removal is urgent in many places, especially in sub-Saharan Africa. Integral management involving trees is vital for genuinely sustainable intensification for the rising global population's food security. A global policy framework for forest stewardship must be rigorously applied by each nation. However, only by engaging indigenous people and integrating tree care within their livelihoods can progress be attained towards sustainable agriculture within ecosystem security. Only by respecting cultural connections of rural communities as integral to that ecosystem security can geopolitical stability be pursued with hope.

About the author

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Useful websites

FAO Forestry: www.fao.org/forestry All issues of *Unasylva* (published in English, French or Spanish) are available online free of charge at www.fao.org/forestry/unasylva

Forest Stewardship Council (International): https://ic.fsc.org/

Forestry Commission Statistics: www.forestry.gov.uk/statistics

The Green Belt Movement: www.greenbeltmovement.org

World Agroforestry Centre: www.worldagroforestry.org

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REFEREED ARTICLE

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The economics of biogas in Denmark: a farm and socioeconomic perspective

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ABSTRACT

Denmark has been one of the leading European Countries in using Biogas for Combined Heat and Power (CHP), since the 1980s. However, in the last two decades, the increase has been limited. A new energy policy aimed at increasing the profitability of biogas was introduced in the spring of 2012. The analysis here shows that the new agreement will improve the profitability of biogas plants and increase the biogas production although the political ambition of an increase from 4 PJ to 17 PJ by 2020 seems unlikely. The analysis shows that biogas plants can be profitable even if the input is a mix of manure and solid fractions/ farm yard manure given the present level of support. The overall production costs are around €0.63 per m^3 methane produced, but they can vary from 0.47–0.78 per m^4 methane produced[3]. The profit in the CASE 2012 analysis is €420,000 per year or 0.0.8 € per m^3 methane. The analysis shows that the profit from upgrading biogas is only to be preferred if the sales price of heat or the amount sold are relatively low. The socioeconomic analyses show that the costs of biogas as a measure to reduce CO_2 emissions are around €151 per tonne CO_2 (€85–266 per ton) and that using maize is an expensive way to reduce emissions of CO_2. In an analysis comparing the Danish and German support system, it has been found that the German socioeconomic costs seem to be five times higher than the Danish, based on the same calculation method. In order to improve profitability and reduce the cost of reducing CO_2 emissions, the input to the biogas plant has to be based more on farm yard manure and deep bedding, although the cost of using these inputs might be higher than was included in the analysis.

KEYWORDS: Economics; upgrading biogas; cost of CO_2 reduction; mitigation

1. Introduction

The EU targets on renewable energy, to whose realisation biogas production contributes, are established to reduce the EU's dependence on fossil fuels and to mitigate the climate changes. Denmark is obligated, by 2020, to decrease its total GHG emissions by 20% in the non-ETS[3] quota sectors (housing, transport and agriculture), compared to the 2005 emission levels (European Council, 2009b and 2009a). Along with several initiatives, the Danish politicians made a 'Green Growth' agreement in 2009, stating that up to 50% of all Danish manure should be utilized in a biogas plant by the year 2020. The Danish aims are, therefore, greater than the European requirements as the aim for 2020 is to increase the share of renewable energy in the total Danish energy supply system to 30% (European Commission, 2011; KEMIN, 2012). The aim for 2050 is a fossil free energy production.

The European biogas production was 8,346 ktoe in 2009 (toe=tonne oil equivalent=42 GJ) (Eurobserv'er, 2010). Of the total production, 52% came from agricultural biogas, 36% from landfill gas and the rest from sewage gas. Half of all biogas produced in EU is produced in Germany. The UK is the largest producer of landfill gas which is used either to produce electricity or is injected into the gas grid. In Denmark, 74% of the 100 ktoe produced comes from agricultural biogas. Germany produces 50% of the EU-electricity which is based on biogas, but only 18% of the EU-heat produced is based on biogas. In 2009 Denmark produced almost as much heat based on Biogas as Germany, the reason being that the combined heat and energy concept used in Denmark has led to a high heat production, whereas Germany has many plants which produce only electricity. The combined approach can give an energy efficiency of 85%, whereas it is around only 40% when only the electricity is used (Jacobsen, 2012). Germany has by far the highest number of biogas plants (over 7,000 farm biogas plants), with Austria (300), Netherlands (100) and Denmark (60). Denmark has the most centralised biogas plants in the EU (20) (Birkmose *et al.*, 2007).

Currently, 7–8% of the manure produced in Denmark is used for energy purposes, which is relatively high in Europe, but much lower than the Danish aim of 50%. This puts the need for expansion of the Danish biogas production into perspective (Olesen *et al.*, 2012). The majority of the Danish centralized biogas plants were built in the period 1987–1996, and 19 of these plants are

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[4] In mid-March 2014, €1 was approximately equivalent to US$1.39, £0.84, and 7.46 Danish Kroner (DKK).

Table 1: Energy price (old and new agreement)

	Old energy agreement, CHP (€/Nm^3 methane)	New energy agreement CHP (€/Nm^3 methane)	New energy agreement, natural gas grid (€/Nm^3 methane)
Governmental subsidy	0.380	0.497	0.497
Natural gas price	0.312	0.312	0.312
-Upgrading costs	0	0	0.168
(Quota value)	0	0	(0.048)
(Green value)	0	0	(?)
Total	**0.692**	**0.810**	**0.642**

Source: Tafdrup, (2012), KEMIN, (2012)

still operative today. Alongside this development, around 60 smaller farm scale biogas plants were established. These are responsible for the small but constant increase in Danish biogas production from the mid 90's until now. The biogas production based on manure, has doubled from 1.5 PJ/year in the year 2000 to 3.0 PJ/year in 2010. The total Danish biogas production was 4.2 PJ/year in 2010 (Energistyrelsen, 2010).

The new Danish energy agreement was implemented in the Spring, 2012. To promote the utilization of Danish manure to energy purposes, the governmental support for biogas-based energy was increased from €0.380/Nm^3 methane to €0.497/Nm^3 methane[5], under the condition that the biomass input consists of at least 75% manure. Furthermore, it became possible to get a subsidy for the injection of biogas into the natural gas grid. Finally, to kick-start the production, an investment subsidy of 30% was given to 19 biogas plant projects in 2012. The higher governmental support and the high investment subsidy together with the increased production and sales opportunities, have improved the regulatory framework and the potential income in the Danish biogas sector.

The purpose of the paper is to analyse whether the new energy deal makes Danish biogas profitable from a company perspective, based on the analysis of a CASE 2012 plant. What are the changes in profitability due to e.g. choice input, price, subsidy and share of maize? Will the price conditions in the new energy agreement be enough to boost biogas production in Denmark to fulfil the political ambitions? Furthermore, the aim is to look at the production of biogas as a measure to reduce CO_2 emissions. Is biogas a cost-effective option and under what conditions? With the rapid expansion of biogas plants in Germany, it is relevant to compare the support system and the socioeconomic costs of CO_2 emission in Germany with the Danish situation, looking at both the farm- and socio-economic incentives.

2. Danish biogas

The new Danish energy agreement has increased the value of biogas. As Table 1 illustrates, the governmental support for Danish biogas has increased by approximately 30% compared to the old energy agreement. Table 1 also shows the total price of biogas when it has been upgraded including the natural gas price, the extra costs related to upgrading the biogas to natural gas quality, the values of unused quotas, and a possible green value of biogas.

As mentioned, Table 1 also illustrates a quota value in relation to biogas on the natural gas grid. This value is not a reality yet, but a certificate system has been implemented in the Danish natural gas grid, so consumers are able to buy the CO_2-neutral biogas instead of the standard natural gas. This option allows the energy company to save quotas and the value is with an EU quota price of €20 per ton CO_2, equivalent to a price of €0.048/Nm^3 methane. It should be noted that the current EU CO_2 quota price is only €3–5 per ton CO_2. The table finally contains a green value, which is the value companies/consumers are willing to pay for the CO_2-neutral energy in order to improve the companies green image. It should be noted that CO_2 in this article refers to CO_2-eqivalents as it includes the full effects of all Green House Gases (GHG).

The change in the regulatory framework, providing the possibilities for upgrading biogas to natural gas quality and injecting it into the natural gas grid, has a huge effect on the sales possibilities of biogas. Earlier, the biogas producers were forced to sell their biogas to the local CHP (Combined Heat and Power) plant, and with no alternative buyer, a relative low price on biogas was standard. With the new energy agreement, the biogas producers have an alternative buyer, which improves their situation when negotiating energy prices. The change, furthermore, enables a production of biogas in remote areas far from any CHP plants, which is necessary, if the target of degassing 50% of the Danish manure production is to be realized.

With the new energy agreement, an investment subsidy of 30% is available for a biogas plant project, if their application was approved by the end of 2012 and with the building starting in 2013. This has resulted in 42 applications and the approval of support for 19 new biogas projects in Denmark. Due to the long ratification process in the EU, the support based on the agreement from 2012 is ready to be paid out only from the end of 2013. The plant size ranges between a reactor capacity of 50,000 tons per year for farm scale biogas plants, to larger centralized biogas plants with the capacity to process almost 500,000 tons of biomass per year.

Finally, the ability to boost the biogas production with energy crops and still be eligible for the governmental support, has also improved the conditions for the biogas producers. After the approving of the new energy agreement, a debate was initiated concerning whether it was wise to subsidize biogas based on energy crops (maize). The concern was that biogas, based on energy crops, does not reduce GHG emissions as efficiently as manure, and that it would not contribute

[5] A Normal Cubic Meter of a gas (Nm3) is the volume of that gas measured under the standard conditions of 0 degrees Celsius and 1 atmosphere of pressure

to the realization of the target of degassing 50% of the Danish manure production by 2020. On that foundation, it was agreed to reduce the eligible share of energy crops in the biogas input mix, from 25% in 2012, to 10% towards 2020, and maybe even to 0% in the following years.

3. Case 2012 biogas plant

The analysis is carried out for a hypothetical biogas plant called Case 2012. In the analysis assumptions regarding the plant size, the biomass input mix, the biogas production, and the energy output has been made based on the conditions in Denmark in 2012 and data from some of the 19 plants which received an investment subsidy in 2012. It is estimated that the average new centralized biogas plant in Denmark will have a capacity to degas approximately 700 ton biomass per day, which amounts to almost 260,000 ton biomass per year. The size of the engine is around 2–3 MW. The biomass input mix is based statements from new and planned Danish biogas plants. The input mix does not provide the highest possible profit for the biogas producer, but it is the most likely combination as the allowed share of maize-silage will be reduced to 10% over the coming years. Furthermore, 12% of fibre fraction was added to boost gas production. It is assumed that organic industrial waste is no longer available for the biogas producers, as it already is fully utilized by the current Danish biogas production. Table 2 illustrates the capacity of the biogas plant, the shares of different biomasses in the input mix and their dry matter content, along with the total biogas and methane production.

A part of the produced biogas is utilized in the engine in the biogas plant as process energy, which receives a governmental subsidy of €10/GJ. It is estimated that the process energy is equivalent to approximately 2 m^3 methane per ton biomass input. Furthermore, 1% of the biogas is lost through flaring, and 10% of the biogas is lost through lack of demand for biogas-based heat in the summer period. The final amount of biogas available for sale is 6.1 million Nm^3 methane per year. The production in the first year is reduced by 25% as the system is not performing at maximum capacity right from the start.

The dry matter content in the Danish manure is one of the most uncertain parameters when estimating the biogas potential for a given biogas plant. This uncertainty exists because the dry matter content varies drastically with the type of manure. The dry matter content in cattle manure is generally the highest, whereas the manure from pigs, especially sow slurry, is lower. The standard Danish values for the dry matter content for 2012 are 4.5% for sow slurry, 6.1–6.6% for slaughter pig manure, and 9.3% for cattle (Århus Universitet, 2012). However, the actual tests show lower dry matter values due to larger water content. The most up-to-date values on the dry matter content in the Danish manure are lower than the standard values. Birkmose *et al.* (2012) estimate the dry matter content in manure from slaughter pigs to be 5.5%, and 4.0% for sow slurry. The dry matter content in cattle slurry is estimated to be 7.5%.

Looking at separated manure, it requires 11.5 tons of cattle manure, or 10.8 tons of pig manure to produce 1 ton fibre fraction with a dry matter content of 33%. As shown in Table 2, the methane production per ton is five-six times higher than for slurry. Maize increases the gas production even more (100 Nm3/ton biomass), but as the crop competes with other crops like wheat, a payment of €41 per ton has to be made to the farmers (Jacobsen *et al.*, 2013).

Instead of boosting the biogas production with energy crops, the biogas producer could use separated manure to increase the dry matter content in the reactor. The gas potential in separated manure is not as high in relation to its price, compared to that of maize silage, so it depends on the price paid for the solid fraction from separation. Here, it is assumed that the biogas plant will have to pay €12.1 per ton of solid fraction the biogas plant receives.

4. Results

The standard centralized biogas plant of 250,000 tonnes per year is estimated to have a plant-investment cost of €10.7 million, followed by additional investment costs in e.g. trucks, land, and pipeline, which bring the total initial investment costs up to €13.2 n. Besides the initial investments, there will, after 10 years, be a need for reinvestments of approximately €2. The annual maintenance costs are €0.2 m. A total of three people will be employed with a salary of €0.2 m per year.

Finally, there are the transport costs. It is estimated that the new centralized biogas plant will have an average distance to its manure suppliers of 14 km. Few plants have invested in manure pipelines to transport the manure and so the main part of the manure is transported by truck. This is one of the most costly parts of biogas

Table 2: Biomass input and production–2012 case biogas plant

Biomass type	Input amounts (ton/year)	Dry matter content (%)	Methane (1000 Nm3/year)	Biogas (1000 Nm3/year)	Methane (Nm3/ton input)	Biogas (Nm3/ton input)
Cattle manure	86,553	7.5	1,039	1,598	12.0	18.5
Pig manure	112,737	4.9	1,237	1,904	11.0	16.9
Seperated pig manure	17,344	30.0	1,082	1,665	62.4	96.0
Separated cattle manure	13,316	30.0	831	1,278	62.4	96.0
Maize silage	25,550	33.0	2,552	4,641	99.9	181.6
Extra (serie-operation)	-	-	674	1,109	-	-
Total	**255,500**	**11.3**	**7,416**	**12,194**	**29.0**	**47.7**

Source: Jacobsen *et al.*, 2013.

production, especially because the manure consists mainly of water. The annual cost of transporting 200,000 tonne of manure amounts to approximately €0.5 m.

The interest used is 7.5%, as banks do not always use the biogas plant as collateral. Therefore, it requires that the farmers can used their farm as collateral for the investment. This can, together with funding from the special credit cooperation (Kommunekredit), give a low interest. In the case that the farmers have low equity and more external capital is needed, it is likely that the average interest would be around 7–8% as external investors are invited in. They will often demand a return of 15% per year on their investment.

Table 3 presents the costs related to a standard centralized biogas plant with the capacity of 700 ton biomass per day. The biomass, in this example, consists of 78% untreated manure, 12% separated manure, and 10% maize silage. The annual costs over the 20 year plant lifetime, are in this case estimated to close to €3.2 m. The costs per m^3 input and produced gas (not sold) gas production are also shown.

The income from a standard centralized biogas plant depends on who the buyer is. By selling the biogas to a local CHP plant, the biogas producer will not get paid for approximately 10% of his energy production due to the low demand for heat in the summer period. On the other hand, if the biogas producer chooses to upgrade his biogas for injection into the natural gas grid, extra costs for upgrading the biogas to natural gas quality will appear. In the best case scenario, the centralized biogas plant is situated near a very large CHP plant which has the capacity to receive and sell all the biogas which is produced. If the centralized biogas plant is located far from the nearest local CHP plant instead, it might be more profitable to inject the biogas into the natural gas grid, despite the extra upgrading costs.

Table 4 illustrates the income from the sale of the methane produced at the standard centralized biogas plant. Besides the methane sale, degassing the manure increases its fertilizing value from which the biogas producer also gains an income. Finally, the biogas producer has to buy the energy crop and pay for the separation of the manure which is used to boost the energy production.

5. Sensitivity analysis

As the calculations show in Table 4, a centralized biogas plant which sells the biogas to a local CHP plant will gain an annual profit of €1.6 per ton biomass, or €0.4 million per year. The basic assumptions are shown in Table A in appendix 1. If the centralized biogas plant were to upgrade its biogas and inject it into the natural gas grid, the calculations would be rather different. The income from gas sale would increase by 6% as all the gas is sold, but the additional costs due to the upgrading is assumed to be €0.13/Nm^3 methane, equivalent to €4.35 per ton biomass. In total, this would give a deficit of €0.1 million per year. However, in the case of an increase in sales price of €1.3 per m3 methane, the profit would be €0.3 m per year. The higher price could come from the need to use Green energy as discussed earlier. Another aspect is that if the natural gas company were the owner of the biogas plants, they would be able to provide the capital at an interest of 3–4% and not 7.5%, which would lower the financial costs by €0.3 m per year.

As shown in Table B in Appendix 1, the highest production costs are related to a large share of slurry and when the dry matter content is low. Low production costs are found in cases with a larger share of deep bedding and when the energy loss is reduced.

There is a need for approximately 20–30 new biogas plants, besides the existing 20 in order to reach the Danish target of 50% of all the manure produced being used in a biogas plant. This potential substantial increase of new biogas plants would mean that they cannot all be located near a local CHP plant, as the available manure becomes increasingly scarce. Some of the new biogas plants need to be located in lower livestock intensive areas, where there are no local CHP plants. Therefore, upgrading to natural gas quality and injecting the biogas into the natural gas grid, becomes the only option. But here also, the higher the quantity, the cheaper the cost of upgrading per unit of methane. Another option would be for farmers to join their farm biogas plant in a biogas grid and connect to an upgrading plant. It is clear, that reaching the target of 50% calls for a high degree of farm participation in biogas production which can be difficult to achieve. A possible distribution of the plants to reach the 50% target based on the lowest transport distance is shown in Jacobsen *et al.* (2013).

6. Calculating CO_2 mitigation costs

The political target within the EU is to reduce the CO_2 emissions by 20% by 2020 for the non-quota sectors

Table 3: Total annual costs for a biogas production (Case 2012)

Annual costs	1000 € per year	€ per ton input	€ per m^3 biogas	€ per m^3 methane
Electricity	193	0.75	0.02	0.02
Investments	1,292	5.08	0.11	0.17
Reinvestments	62	0.24	0.01	0.01
Maintenance	218	0.85	0.02	0.03
Transport of slurry	662	2.59	0.05	0.08
Transport of energy crops	318	1.25	0.03	0.04
Transport reinvestments	76	0.30	0.01	0.01
Running costs	372	1.46	0.03	0.05
Total	**3,192**	**12.5**	**0.26**	**0.43**

Source: Jacobsen *et al.*, 2013

Table 4: Total income and costs

Income	1000 €/year	€/tons input	€/m^3 biogas	€/m^3 methane
Gas sale	5,122	20.00	0.42	0.69
Increased fertilizer value	207	0.81	0.02	0.03
Purchase of biomass	−1,715	−6.71	−0.14	−0.21
Total costs	3.192	12.5	0.26	0.43
Total profit	422	1.6	0.04	0.08

Source: Jacobsen *et al.*, (2013)

(agriculture, housing and transport). Denmark has recently set a higher target of 40% (The Government, 2013). A key question is whether biogas is a cost effective way to reach the target. This type of analysis can be conducted in different ways, but they all include some key questions, which need to be answered:

1. How to calculate the CO_2 effect of replacing current energy with biogas
2. How to include side effects which have an impact on society and other environmental goals
3. Whether product or consumer prices should be used to perform the cost calculations included in the MAC (Marginal Abatement Cost) curves.

Question 1: calculating CO_2 effect

Calculating the CO_2 reduction from changing the present energy form to biogas is mainly done in two ways. One approach is based on a calculation where the current energy source (e.g. natural gas or coal) is replaced by the different types of biomass. Here, the effect of natural gas substitution as well as e.g. lower methane and carbon storage is then calculated and converted to the CO_2 equivalents (see Dubgaard *et al.*, 2011 and 2013). The alternative approach is based on a Life Cycle Analysis (LCA) where the full CO_2 impacts of e.g. the process of building a traditional energy supply and biogas plant is compared (Scholz *et al.*, 2011 and Meyer-Aurich *et al.*, 2012).

Question 2: Side effects

The social economic advantage of the shift to biogas is related to CO_2 emissions, but other factors also need to be valued. In the Danish context, lower N-leaching and reduced smell can be named as two advantages which could be valued. For side effects, where a political target exists, a shadow value, based on the costs of other measures, are used as the price the society will pay for this improvement. In a Danish context, the shadow price has been set as the marginal costs of measures which have been decided politically to reduce e.g. ammonia emission or N-leaching.

Question 3: Prices used

Where most countries use factor prices, the tradition in Denmark has been to use consumer prices in a socio-economic analysis in order to be able to compare costs and benefits. This is because the benefits used are based on consumer estimates which include VAT etc. In order to convert factor prices to consumer prices, a net levy factor of 35% is used to convert the factor costs to consumer costs (Ministry of Finance, 1999). This is also a requirement by the Ministry of the Environment that this approach should be used. Furthermore, the fact that the funds used for the subsidy is generated through a tax increase, creates a deadweight loss which should also be included in the cost calculations. The dead weight loss used is 20%. In total, this means that the Danish socioeconomic costs will always be higher than similar calculations in most other European countries.

7. Mitigation costs in Denmark

Degassing of manure contributes to the reduction of GHG emissions in the agricultural sector. Table 5 illustrates the GHG emission reductions related to the degassing of different types of manure. The calculations show that the total GHG reductions are 18,500 tons CO_2-equivalent per year for the CASE 2012 described earlier. The GHG reduction when using maize has no reduction in relation nitrous oxide (NO) and methane and so the full effect of maize comes through the high energy substitution.

We will now look at the estimation of the side effects. Degassing manure also has the ability to reduce nitrogen leaching to the surrounding water. The effect of reduced nitrogen leaching to the root zone is estimated to be 0.11 kg N/ton manure. Less nitrogen leakage represents a welfare economic benefit through the reduction of a negative externality. The welfare economic value of reduced nitrogen leakage to the root zone is estimated to be €4.1 per kg N. When degassing the manure from a standard sized centralized biogas plant, a welfare economic gain of €0.4 m is generated from reduced nitrogen leakages.

Another of the side effects from degassing manure is that the foul odour emission from manure is drastically reduced. Therefore, when the farmers are fertilizing the fields with the degassed manure, the inconvenience for the neighbours is reduced, which generates a positive welfare economic value. No precise estimate of the odour emission reduction value exists, but studies show that the odour emissions are reduced by approximately 50% (Jørgensen, 2009). Furthermore, degassing manure will result in decreased ammonia emissions when distributed on the fields. The biogas plant also functions as a storage and distributer of the manure, which is a benefit for farmers with too much manure compared to their land size.

Besides the above mentioned welfare economic benefits, the biogas production also increases NO_x emissions, which cause damages of €0.3 per ton degassed biomass. The total cost of the CO_2 emissions is €151/tonne CO_2 based on the average case (see Table 6 and Table B in appendix 1). This is much higher than the current CO_2 EU-quota price of €5–10 per ton.

Table 5: GHG emission reductions from degassing pig and cattle manure on a centralized biogas plant

	Cattle manure	Pig Manure	Fiber Fractions (pigs)	Maize
	(kg CO_2-eq./tonne).			
Natural gas substitution	19.0	18.7	171.3	184.3
Nitrious oxide	12.8	11.2	35.9	0
Methane reduction	1.9	13.2	96.7	−60.2
Carbon storage in soil	−1.4	−1.4	−12.8	0
Total effect	32.3	41.7	291.1	124

Source: Olesen *et al.* (2012)

However, looking at other measures in the non-EU quota sector, the analysis show that the marginal costs of CO_2 reductions when trying to achieve the reduction target of 40% or 4 GT CO_2, is around €130–135 per ton CO_2 (The Government, 2013). In other words, with the ambitious Danish target, a cost of around €130–135 per ton CO_2 is just above the level of future target price. The sensitivity analysis in Table B in Appendix 1 shows that the lowest socioeconomic costs come with a high share of deep bedding, larger plants and lower energy loss, whereas the use of maize and input based on slurry and grass have socioeconomic costs over €250 per ton CO_2.

8. Mitigation costs of Biogas in Denmark compared to Germany

The German biogas production has increased dramatically in recent years due to high subsidies for biogas, but does that also mean that the socioeconomic costs per CO_2 are high? Today biogas covers around 1% of the total energy consumption in Germany, using 800.000 ha of maize in 2010 as most biogas plants have maize as the main input. This has put pressure on dairy farming in Germany as the land prices have increased and the transport of maize even from Denmark (10,000 ha), more than 100 km away, has been a very lucrative business, due to the high German subsidies. The analysis of the costs of production from SABAP shows that electricity from coal and gas costs around 5.5 cent per kWh as opposed to 19.6 cent per kWh, which is the cost for electricity from biogas (SABAP, 2011).

Calculations done by Scholz *et al.* (2011) show the production costs and the CO_2 mitigation costs for a German biogas plant based on a small 500 kW plant. The energy production per year is 4,100 KWh (el) and the CO_2 emission was calculated to be from 0.11–0.4 kg CO_2/kWh_{el} as opposed to 0.6 CO_2/kWh_{el} in the reference system. The net effect was hence 0.21 to 0.5 kg CO_2/kWh_{el}. The mitigation costs are €459–1,135 per ton CO_2 where the lowest cost is related to scenario II based on slurry and maize, including the use of thermal heat. This cost is higher than SABAP (2011), which states a price of €200–300 per ton CO_2 depending on the reference system. This could indicate that the socioeconomic costs, based on LCA, are higher than when based on the direct calculation of CO_2 reduction. This is based on the assumption that the costs of production, the biogas production and the reference energy technology are the same in the two cases.

It is now possible to compare the Danish social costs of biogas with the German costs. First, it can be noted that the Danish costs without side effects and consumer price conversion and deadweight loss are substantially lower €101 per ton compared to €151 per ton when these effects are included (see table 6). The most cost effective method (deep bedding) now has a cost of €25 per ton as opposed to €56 per ton when all taxes are included.

The calculations show that the socioeconomic costs in the German case with use of heat is five times higher than the Danish 2012 case and ten times higher when the heat is not used (which is often the case) (see Table 6). One of the main explanations is the large share of maize used in the German biogas plants. The Danish results also show that the cost when using maize (23% of all input) has twice the socioeconomic costs of the standard case. When the most cost efficient Danish option was used, (deep bedding) the difference to the German costs are even higher. The effect of German biogas can be increased if the present energy mix used in the calculations is changed to 100% coal instead of an average mix. However, if natural gas is used as the current energy input (as in the Danish case), this would reduce the mitigation potential and further increase the German mitigation costs. Looking at other renewable energy options in Germany, analyses have shown, that solar panels also have a mitigation cost of around €500–600/ton CO_2, whereas wind power has a

Table 6: Socioeconomic results–Danish calculation for a Danish biogas plant–700 ton/day

	1000 €/year	€/m^3 biogas	€/m^3 methane
Total costs	5,302	0.43	0.67
Total income	2,872	0.25	0.39
Total value of dead weight loss	730	0.06	0.09
Total value of side effects	301	0.02	0.04
Total deficit (NPV 20 year)	2,791	0.21	0.32
Total CO_2-eq reductions. (ton)	18,4		
MAC (€/ton CO_2-eq.)	151		

Source: Jacobsen *et al.* (2013)

mitigation cost of €40–50 per ton CO_2. In other words, biogas has the same level of abatement costs as biogas in Germany (Marcantonini and Ellerman, 2013).

The promotion of biogas in Germany is related to the need for replacing electricity production from nuclear plants which are phased out by 2022. However, the policy recommendations from 2007 were to use more slurry in biogas and not use the expansion of biogas as a success per say, but let it depend on the most cost efficient strategies. The reasons were that biogas was too costly per ton CO_2, the technology does not improve over time and it affects agricultural production (higher land prices etc.). The recommendation was to base the biogas plants on more slurry and require a higher use of heat. The Scientific Advisory Board was clear in its recommendations, but they were only partly followed in the 2012 policy on biogas support (SABAP, 2011). The high support for biogas is probably also linked to the high political ambitions in Germany of at least 35% renewable energy by 2020, reducing CO_2 emission by 40% by 2020, compared to 1990.

9. Conclusions

As a results of the new energy agreement from 2012 and a new policy objective of using 50% of livestock manure to produce biogas, Danish politicians have changed both objectives and the framework for future biogas production. Based on 18 planned facilities, the average size is expected to be approximately 700–750 m^3 per day or 250,000 tons annually. The new energy agreement gives a direct subsidy of €15.4 per GJ. However, increases in other taxes reduce the net effect to €13.8 per GJ. The increased grants provide a significant boost in earnings, but the selling price in real terms will decline over time as the grants are phased out over time. The calculations show that larger plants have lower costs per m^3 of methane produced. This is due to lower operating costs. The transport distance from the farms to the biogas plant of 14 km is a key parameter here. The analysis shows that almost 40% of all costs are related to transportation costs. The large plants can expect that transport costs per m^3 of methane produced can be increased slightly due to longer driving distances. The withdrawal of support for the construction investment of 30% cost the biogas plant 2 million DKK per year. Losing this support can complicate financing, but the biogas plant should still make a profit without the investment support, but strict planning of e.g. inputs is required. Analyses show that the cost of upgrading biogas for distribution via the natural gas grid is roughly the same for the analyzed upgrading techniques. The total cost of the upgrade is set to 0.13 per m^3 of methane including pressure equalization. Profits after upgrading will be less than when selling to CHP when an acceptable price on heat is given. The natural gas companies are in a key position as they have the capital, and so a partnership with biogas plants could be profitable to both parties. It is estimated that with the new energy deal biogas production in the coming years will increase by around 20 plants, taking the use of animal manure to 20–25%. However, financing and finding locations for new biogas plants are key challenges which must be resolved. The analyses indicate that achieving the objective of using 50% of livestock manure in biogas production by 2020 will be very difficult to achieve. However, even an increase from 8% to 20–25% of slurry going through a biogas plant is a large share in European terms.

The socio-economic cost, by increasing biogas production, has increased with the latest energy plan and the change in calculation methods adopted. The new calculations show that costs of up to €134 per ton CO_2 could be required to reach the Danish targets of a 40% CO_2 reduction in the non-quota sector by 2020. Danish analyses shows that mitigation costs in the transport sector are typically higher than €134 per ton CO_2 (Government of Denmark, 2013).

A comparison with the socioeconomic costs in Germany shows that the German politicians have accepted a cost which seems to be around five times higher than the Danish costs per ton CO_2. Germany seems to have been very eager to make a change (biogas

Table 7: Comparison of socioeconomic costs of CO_2 mitigation through biogas based on different calculation methods

Biogas plant	Method 1	Method 2	Method 3
Sideeffects included	Yes	Yes	No
Consumer prices and deadweight loss	Yes	No	No
Results	€/ton CO_2		
Case 2010 205 report[5)]		−24	108
Case 2012[1)]	151	85	101
Case 2012 based on deep bedding[2)]	56	20	25
German–type 1: Use of heat[3)]			459
German–type II: No use of heat[4)]			1135

Note: The German method is based on no sideeffects, no change to consumer prices, no dead weight loss and the LCA method for calculating the CO_2 effect
[1)]DK-Scenario 0 - CASE 2012 (2 MW, slurry, solid fraction and maize, heat is used)
[2)]DK - Scenario 4b–(2 MW, slurry and deep bedding)
[3)]GER- Scenario 2: 500 kW, 4.100 MWh, input slurry and maize, heat is used. LCA for CO2 effect. Biogas is replacing current energy mix
[4)]GER - Scenario 6: 500 kW, 4.100 MWh, input maize and heat is not used. LCA for CO2 effect. Biogas is replacing current energy mix
[5)]Dubgaard *et al.* (2011) FOI report 205
Sources: Jacobsen *et al.* (2013); Scholz *et al.*, 2011 and Dubgaard *et al.* (2011)

and solar power) with high social costs as the consequence of the political choices made.

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Appendix 1: Table A Key assumptions made for the Case 2012 calculation

	Case 2012
Biomass (ton per day)	700
Investment including pipes to CHP unit (million €)	13
Average distance from farms to biogas (km)	14
Interest (%)	7,5
Natural gas real price increase (%)	3
Slurry share of total input (%)	78
Maize share of total input (%)	10
Fibre share of total input (%)	12
Average methane prod. Per ton input (Nm^3/tons)	29
Average sales price for biogas (€/GJ)	19
Energy lost at CHP unit (%)	10
Investment support (%)	0

Source: Jacobsen *et al.* (2013)

Appendix 1: Table B Break even analysis for the Case 2012 biogas plant

	Break even costs (€/Nm3 produced)	Socioeconomic costs (€/ CO_{2eq})
CASE 2012 (700 ton/day)	0.63	151
Larger plant (1000 ton/day)	0.60	138
22% deep bedding	0,47	84
20% maize	0.67	265
93% slurry and 7% grass	0.78	310
Low dry matter content	0.67	159
Lower interest (4.25%)	0.59	---
No loss of energy at CHP unit	0.55	139
Investment support (30%)	0.59	155
Costs after upgrading biogas to natural gas	0.79	228

Note: Based on a production of biogas produced of 7,416 Nm^3. The amount sold after process heat use etc. is 6.102 Nm^3 (82%)
The socioeconomic interest used in the mitigation calculation is 4.25%
See Table A above for the base values
Source: Jacobsen *et al.* (2013)

REFEREED ARTICLE

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Calculating full costs for Swiss dairy farms in the mountain region using a maximum entropy approach for joint-cost allocation

MARKUS LIPS[1]

ABSTRACT

Using data from the Swiss Farm Accountancy Data Network (FADN), this paper derives the full cost for all enterprises–also called 'activities' or 'production branches'–of a sample of 44 Swiss dairy farms in the mountain region. For the joint-cost assignment among enterprises, we apply an approach based on maximum entropy, leading to a disproportionate allocation. The costs per kilogram of milk are calculated on the basis of enterprises involved in dairy production such as roughage, dairy-cow husbandry and calf rearing. Said costs come to CHF 2.40 on average and CHF 2.13 for the median farm. Both results are over three times higher than the producer price, highlighting the significance of other income sources such as direct payments. Labour and machinery are the most important cost items, accounting for 62% and 14% of total costs, respectively. Furthermore, the analysis reveals significant negative correlations between the full costs for milk on the one hand, and farm size measured in livestock units and farm income per family annual labour unit on the other.

KEYWORDS: full costs; dairy; joint cost allocation; enterprise; Switzerland, FADN

1. Introduction

For years, the income of farms in the mountain regions has been modest compared to the income earned outside agriculture. For instance, in the years 2009 to 2011, a full-family workforce involved in mountain farming earned CHF 24,424 a year, while the comparable income in the industrial or service sector, CHF 62,617, was more than double that (Schmid and Roesch, 2012)[2].

Dairy farms–the main farm type found in the Swiss mountain region–contribute to important societal public goods such as grassland maintenance. How to increase income in the long run is therefore a political as well as a business-management question. Basically, there are three options: to increase producer milk prices; to increase direct payments; and lastly, to cut production costs. Owing to Swiss agricultural policy, the producer or farm-gate milk price in Switzerland is substantially higher than in neighbouring regions such as southern Germany or Austria. In 2010, for example, the average producer price for a kilogram of raw milk was CHF 0.62 (Federal Office for Agriculture, 2011), while prices in Bavaria and Austria were CHF 0.38 (€0.31; Agrarmarkt Austria, 2011). A potential free-trade agreement for agricultural commodities between Switzerland and the European Union as currently under discussion would lead to a substantial fall in the Swiss producer milk price, making the first option of increased producer prices less realistic. With the second option, it is important to note that direct payments are higher in Switzerland than in the European Union, averaging almost CHF 73,000 per dairy farm in the mountain region in 2010 (Hoop and Schmid, 2013). Recently passed in the Swiss national parliament, the agricultural policy for the years 2014 to 2017 retains the payment framework of the previous years (Lehmann and Lanz, 2012). To assess the third option of cost reduction, several questions suggest themselves. How high are full costs or full product costs per kilogram of milk? What does the cost structure look like? And finally, is there an economy-of-scale effect, i.e., a negative correlation between full costs and farm size?

Full-cost accounting is a suitable tool for answering these questions. For Swiss dairy production, the International Farm Comparison Network (IFCN) reports the full costs of typical farms (Hemme, 2012). Haas and Höltschi (2012) compile the full costs calculated by Swiss dairy-farm managers. Dorfner and Hofmann (2013) analyse the full costs of over 200 dairy farms in Bavaria. Based on Farm Accountancy Data Network (FADN) figures, the European Commission (2013) calculates full costs–also known as operating costs–for dairy farms in all

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[2] CHF = Swiss Franc. Exchange rates: CHF 1 = €0.81; CHF 1 = US$1.12 (http://fxtop.com, assessed 28 October 2013).

member countries. Using the full costs of several hundred dairy farms in the USA, MacDonald *et al.* (2007) analyse the influence of farm size on profitability.

The allocation of joint-cost items such as labour, machinery or buildings constitutes the main challenge for full-cost accounting. Such costs are normally reported at farm level. If a farm produces more than one output (e.g., milk and cereals), joint costs must be allocated to enterprises (also termed 'activities' or 'production branches'). For this, allocation factors such as working hours–available for all enterprises–are used. In the above-mentioned studies, allocation is performed in a proportional manner, which is a widely applied approach in the literature. Lips (2014) suggested an alternative approach based on maximum entropy. This allows us to discard the assumption of a proportional joint-cost allocation. In addition, as shown for arable crops, the choice of the allocation method is empirically relevant, since there were differences in a range of −16% to +18% between a proportional and a disproportionate allocation. For the full cost analysis of dairy farms, we take advantage of the new technique and apply the disproportionate joint-cost allocation. A proportional allocation is performed at the same time, offering the option of comparing allocation results, which is of interest from a methodological point of view.

This paper is organised as follows: Section Two presents the data from the Swiss FADN as well as the allocation factors, while Section Three provides a brief summary of the disproportionate joint-cost allocation and explains the necessary extension when simultaneously analysing crops such as roughage and animal husbandry sectors. Furthermore, the conversion from enterprise costs to cost per kilogram of milk is presented in detail. Section Four comprises the results, while Sections Five and Six are devoted to the discussion and conclusion, respectively.

2. Data

Because of the focus on dairy production in the Swiss mountain region, we use the accounts of Swiss FADN specialist dairy farms in mountain zones 1 to 4 for the year 2010. There are two factors that lead us to select appropriate farms from the 507 available observations. Firstly, since we focus on agricultural activities, farms involved in agriculture-related activities of over CHF 5000 in value, such as direct sale or gastronomy, are excluded. Otherwise, a shortage of available data would make it impossible to allocate joint costs, especially joint labour costs. Secondly, we must exclude those farms using a substantial share of milk for the fattening of calves, an activity which, based on the available data, is difficult to distinguish from milk production. To this end, we define a maximum quantity of 5000 kg of milk which is not sold as raw milk, but consumed by the farmer's family or used on the farm (though not in the rearing of calves as replacements for the dairy herd[3]). This provides us with a sample of 44 dairy farms. Table 1 presents the characteristics of both the selected sample and the weighted average of all FADN dairy farms from the mountain region. Generally speaking, the selected farms are smaller in size and have lower incomes[4]. The 21.4 livestock units of the analysed sample comprise 15.2 dairy cows, 5.8 breeding animals and 0.4 'other' livestock such as sheep and goats. Seven farms out of the selected sample are run along organic lines.

Because the Swiss FADN provides highly detailed information for both cost items and enterprises, aggregations are necessary.

For dairy production, in order to correctly depict deliveries within the farm, it is essential to draw a distinction at enterprise level between fodder production and animal husbandry. To give an example, fodder produced on the farm can be used to feed dairy cows, or other ruminants such as sheep. Accordingly, we define roughage and silage maize as 'own fodder production' enterprises[5]. For dairy livestock, we distinguish between two enterprises: dairy-cow husbandry, including labour-intensive milking, and the calf rearing which serves as a dairy-herd replacement enterprise. This distinction is motivated by the organisational differences that exist between farms, with some outsourcing breeding, whilst others breed their own future dairy cows on-farm. All activities besides the four dairy-related enterprises are aggregated towards eight additional enterprises, three of which are concerned with plant production: cereals (wheat and barley), forestry, and 'other plant production' encompassing all other activities such as potatoes, peatland and specific ecological areas. Another five enterprises are devoted to animal husbandry: fattening cattle (including suckler cows but not calf fattening), sheep and goats; pork (pig fattening and pig breeding); poultry (poultry fattening and laying hens); and other animals (e.g., horses and donkeys).

Whilst the enterprises of roughage, dairy-cow husbandry and calf rearing are represented on all farms, the number of different enterprises on a farm varies between three and seven out of the 12 enterprises defined. In total, there are 189 enterprises.

With respect to full costs, three categories of cost items can be distinguished for the analysis (Table 2): direct costs, land costs and joint costs. The Swiss FADN includes these categories in different forms[6]:

- Direct costs are recorded at the enterprise level, and are aggregated towards three cost items: purchased feed (feed concentrates and purchased roughage), veterinary services and products (including insemination), and other direct costs (e.g. seeds, fertilisers, and purchase of livestock).
- For land, the FADN provides the total rent figure for leased land, while the opportunity costs of own land are derived by applying the interest rate of Swiss federal term bonds. The average costs per hectare are

[3] Given the limit of 5000 kg delivered milk, calf fattening – which forms part of the 'calf rearing' enterprise – can only take place on a limited basis.

[4] Farm income per family annual labour unit, both for selected samples and for all available dairy farms, is markedly higher than stated in the introduction. Whereas the values in Table 1 refer to the averages of the samples, the indications in of the comparison of income refer to the median, which – owing to cases with very high incomes – is lower than the average.

[5] The storage costs for fodder produced on-farm are accounted for in the 'silage maize' and 'roughage' enterprises.

[6] The cost categories are not directly related to the terms 'variable costs' (varying in direct proportion to the volume of activity) and 'fixed costs' (remaining constant over wide ranges of activities) (Drury, 2004; p. 34). While direct costs belong to the 'variable costs' category, joint costs may belong to both categories. Machinery, for example, includes all costs related to machinery use. Depreciation and interest rates for the invested capital are fixed costs. By contrast, fuel is classified as a variable cost.

Table 1: Characteristic variables of dairy farms in the mountain region 2010

	Unit	Selected sample	Weighted average of all FADN observations
Sample size		44	507
Utilised agricultural area	ha	18.8	22.7
Livestock units	LU	21.4	24.7
Agricultural income	CHF	46,815	50,891
Farm income per family annual labour unit	CHF	30,583	32,216

Source: Hoop and Schmid (2013); Swiss FADN

Table 2: Cost categories and cost items

Total costs	Cost categories	Cost items
Full costs	Direct costs	Purchased feed Veterinary Other direct costs
	Land	Land
	Joint costs	Labour Machinery Buildings Other joint costs

Note: The shaded cost items include opportunity costs for remuneration of family-owned factors

calculated with the assumption of homogeneous land quality[7].

- All joint costs are provided by the Swiss FADN at farm level, and are aggregated towards four cost items: labour, machinery, buildings, and other joint costs (including energy, telephone, insurance, and further training). As regards labour, the FADN reports farm-level labour input measured in normal working days. The allocation is performed in the form of working days rather than labour costs. Working days are then rated with an opportunity cost of CHF 280 (10 hours per normal working day at CHF 28 per hour; Gazzarin, 2011). The machinery costs include depreciation and interest on invested capital, as well as repair, maintenance and fuel costs. Machines associated with animal husbandry such as milking parlours are also considered part of machinery costs. Building costs take account of depreciation, interest charges and maintenance. For both machinery and buildings, we apply the interest rate for foreign capital and opportunity costs (Swiss federal term bonds) for own capital.

The summary of the analysis contains the eight cost items listed in Table 2. All cost items are shaded, including opportunity costs for remuneration of factors owned by the farming family.

Allocation factors are necessary to enable the allocation of joint costs among enterprises. For this, standard costs from farm-management literature are used (Gazzarin *et al.*, 2013; Lips, 2014) or gauged, when no data was available. All values are reported in the Appendix.

3. Method

Joint-cost allocation

For joint-cost allocation, allocation factors or items available for all enterprises (e.g. area or working hours) are typically used (AAEA, 2000). In our case, standard costs (also called budgeted or forecast costs) from farm-management literature are applied. Taken together with enterprise-level information from the FADN, such as the number of hectares, these allow us to calculate the farm-level costs for joint-cost items such as buildings. In doing so, and assuming that the farm's costs are perfectly in line with the standard costs from the farm-management literature, we arrive at the building costs of a particular farm, which can be compared to the farm's actual building costs as reported by the FADN system. Based on these two figures, the deviation factor alpha can be calculated. In other words, alpha represents the ratio of observed farm-level costs (actual costs) to standard farm-level costs. Alpha is then multiplied by the standard costs of the enterprise, which yields the joint costs at the enterprise level we are seeking.

Because alpha is constant across all of a farm's enterprises, it corresponds to a proportional joint-cost allocation. Although widely applied, it represents a strong assumption, since all enterprises are adjusted in the exact same manner, regardless of whether the allocation factor is large or small. Furthermore, the ratios between enterprises (e.g. labour costs of 'forest' and 'dairy-cow husbandry') remain constant.

As an alternative, Lips (2014) suggested a disproportionate joint-cost allocation based on maximum entropy and the allocation factors mentioned above. This approach is based on the assumption that the resultant joint costs at enterprise level lie in an interval between zero and twice the standard costs from the literature[8].

[7] Homogeneous land quality is only assumed for plant enterprises (cereals, silage maize, roughage and other plant production). For forestry, a lower quality and hence a rental rate of CHF 72 per hectare (Albisser et al., 2009) is assumed.

[8] If alpha exceeds 1, the upper boundary is expanded towards 1 plus alpha. Out of the 44 dairy farms, such an adjustment is necessary for the joint-cost items of labour, machinery, buildings and other joint costs for 36, 32, 3 and 14 farms, respectively.

Table 3: Deviation factor alpha for all joint-cost items

	Labour	Machinery	Buildings	Other joint costs
Mean	1.61	1.28	0.52	0.87
Minimum	0.75	0.34	0.03	0.09
Median	1.55	1.18	0.48	0.86
Maximum	3.06	2.44	1.64	1.75

Source: Own calculation using data from the Swiss FADN

Both interval boundaries are assigned probabilities adding up to one–for instance, if both boundaries have a probability of 0.5, this yields the value from the literature. Assuming that a particular farm has lower building costs than suggested in the farm-management literature, the farm's alpha for buildings would be lower than 1, as is the case for the average of the selected sample, as we will see later on (Table 3). Consequently, the building costs fall short of the standard costs for all enterprises of the farm. As regards the above-mentioned interval, the probability of the lower boundary (0) is higher than 0.5, whilst the upper boundary (twice the standard costs) has a probability below 0.5. As a normative approach, the 'maximum entropy' application provides the single and optimal probability distribution for all boundaries subject to a total allocation of actual joint costs at farm level. This approach leads to a disproportionate allocation of joint costs among enterprises, meaning that enterprises with high standard costs undergo a more marked adjustment than those with low standard costs. Generally speaking, maximum entropy provides a probability distribution in which the adjustment of high standard costs is more likely than the adjustment of low costs. This closely corresponds to agricultural reality, in which the higher the standard costs, the higher the possibility of cost adjustment. In addition, since the disproportionate joint-cost approach is applied separately for each farm, a farm-specific joint-cost allocation is provided. In other words, the ratio of the labour costs of one enterprise to another–say, 'forest' to 'dairy-cow husbandry'–can vary between farms.

The method applied (Lips, 2014) represents a further development of a recent conference paper (Lips, 2012), and includes two main differences which are relevant for the present analysis. Firstly, the equation of the Shannon Entropy measure is supplemented with the number of enterprise reference units (e.g. hectares) as weighting factors. Given that the entropy model specification takes place at the reference-unit level, an enterprise of, say, two hectares is treated in principle as two separate enterprises. Since the boundaries are the same, the resultant probabilities are identical for both hectares. Accordingly, a weighting factor allows us to focus on enterprises rather than on individual reference units. Secondly, to ensure that findings from production-technology are borne in mind, inequality restrictions (Campbell and Hill, 2006) are added to the maximum entropy model. Given a clear rank order of an enterprise's standard costs, the inequality restrictions address the differences among said costs. Owing to the disproportional adjustment of maximum entropy, the differences among standard costs should increase steadily upwards. As a difference from the preliminary version, Lips (2014) suggested adding additional activities[9] in order to hone the differences if they are not steadily increasing.

Reference units of enterprises

For crop enterprises, one hectare of land is used as the reference unit (Lips, 2014)–but what reference unit is the most appropriate for animal-husbandry enterprises? Here, two requirements must be met. Firstly, the unit must be consistent within the sphere of animal husbandry–e.g. 'number of animals' would be misleading given the huge difference in the quantity of inputs required for laying hens on the one hand and dairy cows on the other. Secondly, the standard costs per unit should be in a similar range to the costs of plant-production enterprises–otherwise, the treatment of animal- and plant-production enterprises would differ owing to the disproportionate allocation of the maximum entropy approach. To give an example, if the allocation factors for all plant-production enterprises are lower than those of the animal-husbandry enterprises, the adjustment of the latter would be systematically greater. The livestock unit (LU) fulfils both requirements, which is why two reference units–hectares and LU–are applied for the joint-cost allocation (see also the Appendix).

Costs per kilogram of milk

Although the approach described above calculates the full costs for each enterprise, only four of these enterprises–silage maize, roughage, dairy-cow husbandry and calf rearing–are relevant to dairy production.

In order to derive the full cost per kilogram of milk–the core finding of this paper–several steps must be taken to transform these full costs. Here, we make use of additional data provided by the Swiss FADN, such as quantity of milk produced in kilograms.

As a first step, and based on the full costs per hectare of silage maize and roughage, we calculate total costs for on-farm fodder production by multiplying these values by the appropriate number of hectares. Next, we take the full-cost sum of both enterprises. Assuming that all ruminants require the same amount of fodder per livestock unit, we multiply these costs by the share of all ruminants livestock units devoted to dairy-cow husbandry and calf rearing.

Secondly, in order to obtain the total costs of the 'dairy-cow husbandry' and 'calf rearing' enterprises, we

[9] The additional enterprises are treated as additional crops without area, or additional animal-husbandry enterprises without livestock units.

Table 4: Full costs for all enterprises in CHF per hectare or livestock unit

Enterprise	Unit	Number of observations	Full costs in CHF per unit			
			Mean	**Minimum**	**Median**	**Maximum**
Cereals	ha	4	4240	2715	4468	5307
Silage maize	ha	2	8676	4283	8676	13070
Roughage	ha	44	4406	2446	4476	6250
Forestry	ha	28	1068	715	1076	1367
Other plant production	ha	7	16382	4809	14150	30664
Dairy-cow husbandry	LU	44	7992	3537	8211	12940
Calf rearing	LU	44	4658	2337	4783	8054
Fattening cattle	LU	1	6000	-	-	-
Sheep and goats	LU	6	4465	2076	4567	7004
Pork	LU	4	3621	2868	3485	4646
Poultry	LU	1	3650	-	-	-
Other animals	LU	4	3639	2473	3925	4233

Note: ha=hectare; LU=livestock unit
Source: Own calculation using data from the Swiss FADN

multiply the full costs per livestock unit by the corresponding number of livestock units. The resultant costs are then added to the costs from step one, yielding the total costs of all inputs used for milk production[10].

Thirdly, we must consider the by-products of milk production, such as old cows destined for slaughter, and breeding animals which can be sold to other dairy farmers. Assuming a joint production of milk and by-products, the total costs for milk production must be multiplied by the percentage of milk sales out of the total turnover for milk production. Finally, the resultant total costs of milk production are divided by the total number of kilograms of milk produced, less the milk fed to the calves reared for dairy-herd replacement, to obtain the full cost per kilogram.

4. Results

The deviation factor alpha presented in Table 3 gives an indication of the extent to which the farms' actual costs differ from those in the farm-management literature. A value of one would indicate that a farm is completely in line with standard cost. The mean values indicate that dairy farms of the selected sample use far more labour and machinery inputs than suggested. For buildings and other joint costs, inputs are below the level given in the farm-management literature. According to minimum and maximum values, there is substantial variance for all joint-cost items in the sample. The minimum values for machinery, buildings and other joint costs indicate that production at a very low cost is possible.

Table 4 reports the full costs per hectare or livestock unit for all enterprises. In addition to the mean full cost, minimum, median and maximum values are reported for all enterprises except fattening cattle and poultry, each of which is present on one farm only.

On average, the full costs of dairy-cow husbandry come to CHF 7992 per livestock unit. For roughage, dairy-cow husbandry and calf rearing, the minimum and maximum values fall in a range of at least $\pm 40\%$ of the mean values, indicating a substantial variance between farms. The enterprise 'other plant production' exhibits the largest difference between farms, with a maximum value more than six times greater than the minimum value.

The full costs derived per kilogram of milk are depicted in Table 5. In the mean of the sample, costs come to CHF 2.40, of which CHF 1.48 or 61.5% relates to labour, the main cost item. The second-most important cost item is machinery costs, which accounts for CHF 0.35 per kilogram (14.5%). Cost items three and four, purchased feed and buildings, account for CHF 0.19 (7.8%) and CHF 0.14 (6%), respectively.

The average producer milk price realised for the farms analysed is CHF 0.68, with a range at the farm level between CHF 0.49 and CHF 1.03, respectively. The realised price is therefore markedly above the average milk price of CHF 0.62 (Federal Office for Agriculture, 2011), indicating that the milk is primarily made into cheese. Adding up the costs of machinery, purchased feed and buildings gives us CHF 0.68, which is equal to the average producer milk price. Consequently, no other cost item can be covered by the realised producer price.

Figure 1 illustrates the variance while depicting the full costs for a kilogram of milk in an ordered array for all farms. Whereas the lowest total costs stand at CHF 1.23, the highest are CHF 5.73. Between these totals is a factor of more than 4. There is also a group of five farms where full costs of CHF 3.00 are clearly exceeded, an obvious sign that a minority of dairy farms are either subject to specific circumstances (e.g. an extreme event) or have production systems that do not accurately reflect economic realities. The discussion section provides a number of arguments as to why full costs may exceed producer prices.

Table 5 includes the cost structure of the farms with the lowest and highest total costs, as well as the median farm. The main differences are attributable to labour. Furthermore, a comparison of the cost item 'buildings' between the median and the best farm reveals that the farm with lowest total costs does not have the lowest values for all cost items. The farm with the highest total costs also has extremely high values for the cost items 'purchased feed', 'other direct costs' and 'machinery'.

[10] 'Milk production' is used as an umbrella term for the major share of the enterprises 'silage maize' and 'roughage', as well as the full share of the 'dairy-cow husbandry' and 'calf rearing' enterprises.

Table 5: Full costs in CHF per kilogram of milk

Cost item	Mean		Farm with lowest total costs	Median farm	Farm with highest total costs
	CHF	In %			
Purchased feed	0.19	7.8	0.20	0.28	0.41
Veterinary	0.05	2.1	0.04	0.03	0.17
Other direct costs	0.07	2.8	0.02	0.05	0.31
Land	0.04	1.5	0.03	0	0.05
Labour	1.48	61.5	0.55	1.45	3.37
Machinery	0.35	14.5	0.19	0.19	0.99
Buildings	0.14	6.0	0.15	0.03	0.16
Other joint costs	0.10	4.2	0.05	0.11	0.28
Total	2.40	100.0	1.23	2.13	5.73

Source: Own calculation using data from the Swiss FADN

The correlations between full costs and structural and economic indicators presented in the data section are shown in Table 6. As expected, all correlations are negative. For livestock units and farm income per family annual labour unit, the Pearson correlations differ significantly from zero at the 1% level.

5. Discussion

Our results can be compared with two analyses from the literature of Swiss dairy farms in the mountain region. A typical Swiss dairy farm with 18 cows is included in the annual dairy report of the International Farm Comparison Network (IFCN; Hemme, 2012) quoting costs of USD 2.42 per kilogram (approx. CHF 2.16), which are close to those of our median farm. Analysing the full costs of 26 dairy farms in the mountain region for the year 2010, Haas and Höltschi (2012) found that the average full costs came to CHF 1.54 per kilogram of milk. Two factors may be responsible for the differences between their full costs on the one hand and those of our study on the other. Firstly, the dairy farms of the sample they investigated are markedly larger than ours (22 cows on average as compared to 15 cows in our sample). Secondly, the full costs in the Haas and Höltschi sample derive from three subgroups: dairy farmers calculating their full costs as a case study within the framework of their higher vocational education in agriculture; dairy farmers attending a full-cost course or consultation; and dairy farmers organised into working groups, calculating and comparing their full costs. For the second and third subgroups at least, a specific interest in production costs can be assumed. It is therefore likely that these dairy farmers are considering implementing cost-reducing measures, or have even done so already. Consequently, their full costs are markedly lower than those of the FADN sample.

The negative correlation found between number of livestock units and full costs per kilogram bears out Gazzarin *et al.* (2005), showing the gradual decrease in cost as the number of cows increases by means of full-cost calculation for dairy production. Similarly, Jan *et al.* (2011) point out that for dairy farms in the mountain region, farm size has a positive influence on the work income per family annual labour unit.

In addition to the joint-cost allocation by maximum entropy, a proportional joint-cost allocation was also performed as a sort of sensitivity analysis, using the same standard costs as allocation factors. At the enterprise level, the largest differences can be observed for activities which are rarely represented in the sample. Compared to the results set out in Table 4, a proportional joint-cost allocation would lead to deviations for silage maize, other plant production and poultry of +10%, −9% and +13%, respectively. For roughage, dairy-cow husbandry and calf rearing, the differences are much smaller (+1%, −1% and +2%). With regard to the full costs of a kilogram of milk, the deviations at single-farm level between a disproportionate joint-cost allocation and a proportional one fall within the range of CHF −0.01 and CHF +0.05. For the average of all 44 farms, the full cost would be CHF 0.001 lower under a proportional allocation. An important reason for this very slight difference is the fact that the farms in this sample specialise in dairy production. Whatever type of joint-cost allocation is applied, the bulk of it is devoted to milk production.

Since even the best farm has full costs of almost twice the producer milk price, the question arises as to how these farms can continue to operate. Three possible explanations suggest themselves. Firstly, the actual hourly wage rate is lower than the presumed CHF 28. Assuming 280 normal working days of 10 working hours each (see also data section) for a family annual labour unit yields an average hourly wage rate of CHF 10.92 for the 44 farms in question[11]. Secondly, the direct payments must be taken into consideration. Finally, there might be an additional income from off-farm activities at the household level.

6. Conclusions

In this paper, the full costs or full product costs of the enterprises of 44 Swiss dairy farms in the mountain region were derived from accounting data from the Swiss Farm Accountancy Data Network (FADN) using a maximum entropy approach, which provides a disproportionate joint-cost allocation. Because several enterprises such as roughage, dairy-cow husbandry and calf rearing contribute to dairy production, full costs are deduced per kilogram of milk in a subsequent step. The

[11] On-farm income per family annual labour unit of CHF 30,583 (see Table 1) divided by 2800 hours per year

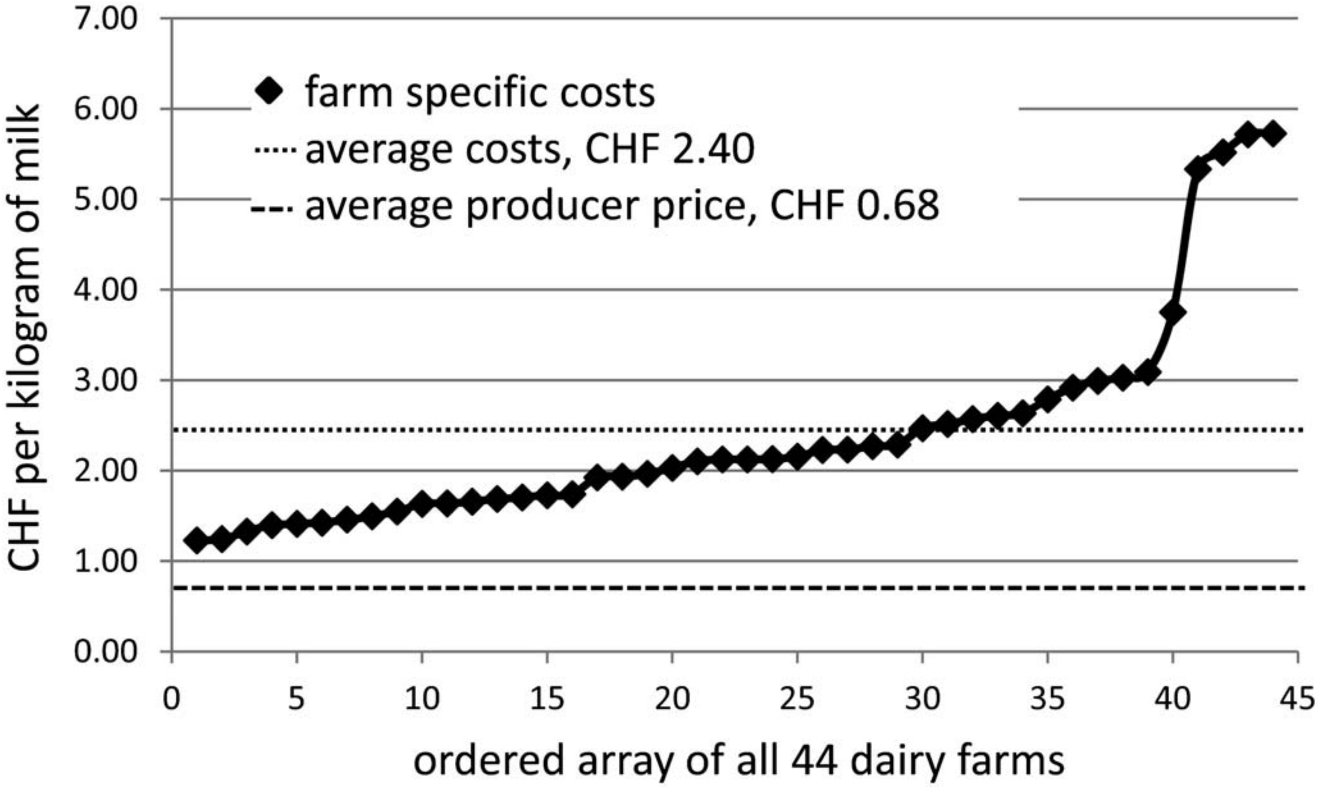

Figure 1: Distribution of full costs for a kilogram of milk

resulting average full costs of CHF 2.40 per kilogram milk are more than three times as high as the realised milk producer price of CHF 0.68. Accordingly, milk production does not even come close to covering costs, and falls far short of the assumed hourly wage rate of CHF 28. Milk production is therefore only modestly profitable, which goes some way towards explaining the chronically low incomes for dairy farmers in the mountain region. Furthermore, the significant negative correlation between full cost per kilogram and farm income per family annual labour unit shows the importance of a cost cut for an increase in income.

The cost structure reveals labour as the main cost driver, responsible for around 60% of full costs. A reduction of labour input per kilogram of milk is therefore a must for dairy production in the mountain region. In other words, a dramatic increase in labour efficiency is needed to cut the cost per kilogram and to increase income per family labour unit. Looking at the dairy farm with the lowest costs in the sample, achieving this objective would appear to be possible. Moreover, an increase in farm size allows advantage to be taken of economies-of-scale effects, and can be achieved e.g. by cooperating with other farmers. The highly significant negative correlation between number of livestock units and full costs per kilogram of milk underscores the promise of such a strategy, and is in line with the literature.

Apart from the importance of labour, the analysis highlights the significance of the three cost items 'purchased feed', 'machinery' and 'buildings'. Taken together, their costs equal average producer price of farms analysed, indicating a clear and immediate need for cost reductions in dairy production. Without a change, the current unbalanced situation requiring additional revenue such as direct payments to cover these expenses in full could be expected to continue. Given the importance of dairy farms for grassland maintenance in the mountain region, the government could support such a process by supplying more information and advice about full costs at the enterprise level for dairy farmers.

Our results are higher than those of the full-cost analysis literature. In addition to farm size, the attitude of the dairy-farm manager might be of importance, given that the study by Haas and Höltschi (2012) is based on the full-cost calculations of dairy farmers, at least some of whom might have an above-average interest in production costs. Accordingly, a selection bias might also be responsible for the differences. The possibility that the farms in our analysis are markedly above-average in terms of full costs cannot be ruled out.

Table 6: Pearson correlations between full costs and characteristic variables of dairy farms

Variable	Unit	Correlation	P-Value
Utilised agricultural area	ha	−0.18	0.239
Livestock units	LU	−0.40	0.007
Agricultural income	CHF	−0.30	0.049
Farm income per family annual labour unit	CHF	−0.40	0.008

In order to clarify these aspects, the analysis must be expanded for all dairy farms from the mountain region in the Swiss FADN. As a precondition it is essential that approaches be developed to cope with both large agriculture-related activities and calf fattening in addition to dairy production.

The present analysis makes use of a disproportionate joint-cost allocation via maximum entropy. The sensitivity analysis, which consists in also running a proportional allocation, reveals substantial differences at the enterprise level. The results for full cost per kilogram of milk are the same, indicating that the type of joint-cost allocation is only of minor importance for the present analysis. Owing to the high degree of specialisation, most costs are assigned to dairy production by whatever means is used to perform the joint-cost allocation.

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Appendix A: Standard costs from farm-management literature

Enterprise	Unit	Labour in normal working days	Machinery costs in CHF	Buildings in CHF	Other joint costs in CHF
Cereals	ha	3.3	1549	160	130
Silage maize	ha	3.7	2629	2509	140
Roughage	ha	5.3	1036	648	150
Forestry	ha	1.0	352	100	100
Other plant production	ha	18.3	4553	310	320
Dairy-cow husbandry	ha	10.5	440	670	400
Calf rearing	LU	8.5	80	933	380
Fattening cattle	LU	14.7	70	827	360
Sheep and goats	LU	6.8	30	676	350
Pork	LU	5.5	15	835	250
Poultry	LU	4.5	10	1104	260
Other animals	LU	6.0	25	600	300

Note: ha=hectare; LU=livestock unit; CHF=Swiss Franc
Sources: Gazzarin *et al.* 2013, Lips 2014, own estimates

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Experience and learning in beef production: Results from a cluster analysis

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ABSTRACT

Research in agriculture and other industries has shown that innovativeness is a key driver of improved performance measures of small and medium-sized enterprises. The willingness to change current practice may be a function of the level of experience of the manager as well as the manager's commitment to learning. Firms with more experience may suffer from confirmation bias and therefore may not see the performance benefits that stem from innovative activities. Using data from a survey of 285 beef producers in Illinois, this study employs cluster analysis to segment firms along experience and learning variables. Using a non-hierarchical clustering procedure, four clusters emerge. The study employs one-way ANOVA tests to examine differences in market orientation, innovativeness and satisfaction with several performance measures across clusters. Results indicate firms with a commitment to learning have a greater propensity to seek out market information, a greater willingness to accept innovations and are more satisfied with overall performance. The paper concludes with some implications for managers and policy makers.

KEYWORDS: Cluster Analysis; Experience, Learning orientation; Market orientation; Innovativeness; Performance

1. Introduction

Previous research in the management literature has indicated prior experience is an important resource for managers (Gimeno, Folta, Cooper and Woo, 1997; Ucbasaran, Westhead and Wright, 2007). One benefit of experience is that seasoned managers may be able to sense market changes more quickly or may be more adept at assessing the value of information (Martin and Staines, 1994). Conversely, greater levels of experience may also lead to increased rigidity in accessing and applying new information (Kim, Oh and Swaminathan, 2006). One method to reduce cultural rigidity is to develop a learning orientation. Firms with a learning orientation continuously gather market information and question their beliefs and practices as it relates to their current operational strategy (Sinkula, Baker and Noordewier, 1997). As lenders and policy makers often view experience as a value-enhancing resource, further analysis into the relationship between experience and learning may shed light on the issue within the context of production agriculture. One method that may help researchers and policy makers to increase their understanding of the issue is cluster analysis. Using data-driven techniques like cluster analysis, researchers can observe patterns in data to inform current discussions while also uncovering potential areas worthy of future research.

Research in agricultural management has suggested that prior experience is an important resource that managers can draw upon (Nuthall, 2009; Wilson, Hadley and Asby, 2001). For example, previous relevant managerial experience may provide managers with prior information that they can use to make managerial decisions regarding the selection of crops to plant, varieties to purchase, timing of field applications, as well as which employee to hire. However, there may be instances where experience impedes innovation (and possibly performance) through structural rigidity (Boeker, 1997; Koberg, Chesley and Heppard, 2000). At the extreme, prior experience can inhibit learning if the manager makes incorrect inferences from the experience (Levinthal and March, 1993). For example, as managers gain more experience, confirmation bias may impede the search for additional perspectives on the competitive landscape (Evgeniou and Cartwright, 2005; Klayman, 1995).

This paper examines a sample of beef producers in Illinois to advance the understanding of the relationship between a firm's learning orientation and experience. Sinkula, Baker and Noordewier (1997, p. 309) define a learning orientation as 'set of organizational values that influence the propensity of the firm to create and use knowledge.' Specifically, this paper will use cluster analysis to examine if homogeneous subgroups exist based on managerial experience and the manager's commitment to learning and open-mindedness, two components of Sinkula, Baker and Noordewier's (1997) learning orientation scale. The beef industry provides an

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interesting context to study the relationship between managerial experience and learning orientation as, in general, technological innovation in beef production has been incremental which may lead managers to rely on their own experience when making decisions regarding the farm business. This might be a suitable strategy, as in less dynamic environments firms may not see performance increases from the development of new resources such as a learning orientation (Covin and Slevin, 1989). Moreover, while Illinois ranks in the middle of U.S. states in terms of beef production, beef production in Illinois has been increasing pointing to a need to better understand performance in a growing industry (USDA -- National Agricultural Statistics Service, 2011).

This paper utilizes a dataset compiled from a 2007 survey of managers of beef farms in Illinois. The data is used to categorize farms into clusters based on their responses to items from learning orientation scale and previous experience in management of beef farms. This paper then uses one-way ANOVA tests to examine if differences in scores of market orientation, innovativeness and performance across groups are significant across cluster groups. Remaining sections of this article will address previous research on learning and performance, methodology, results, and will conclude with a discussion on what the results mean for managers.

2. Literature review

This paper builds upon the literatures on organizational learning and managerial experience to examine issues relating to firm-level innovativeness and performance. Performance of agricultural firms is affected by the broader economic environment as well as specific industry and firm-level factors (Schumacher and Boland, 2005). While industry-level factors are important, recent research has focused more on firm-level factors as the decision maker can influence the development of these factors (Micheels and Gow, 2012; Verhees, Kuipers and Klopcic, 2011). Previous studies have shown that innovative firms are able to achieve greater performance levels (Capitanio, Coppola and Pascucci, 2009; Verhees and Meulenberg, 2004). More recently, authors have begun to examine the effect of alternative orientations such as a market orientation and entrepreneurial orientation on firm performance (Grande, Madsen and Borch, 2011; McElwee and Bosworth, 2010). As the industry changes and firms compete for inputs, employees, and land, how firms evolve to meet these needs through the development and deployment of strategic resources will become of greater interest to researchers and policy makers.

Previous managerial experience and financial performance

Taylor (1975) has shown that older managers tend to seek more information when making a decision and were more accurate in assessing the value of information. Expanding upon this work, Martin and Staines (1994) find that many managers believe competence is a function of industry experience. These studies are based on the assumption that experience may improve decision-making and therefore may lead to greater managerial competence. However, as Argote and Miron-Spektor (2011) point out, there are cases where experience limits creative thinking through the continued use of heuristics that were successful in the past.

Within an agricultural context, Nuthall (2009) suggests there is a dearth of literature on the relationship between managerial experience and performance. Of the literature that does exist, most studies examine the relationship between experience and efficiency. For example, results from Wilson *et al.* (2001) show that managers with more experience, who actively seek information, and who manage large farms are able to achieve higher levels of technical efficiency. More recently, Hansson (2008) finds that managerial experience is significantly related to both short-term and long-term measures of efficiency.

Organizational learning and financial performance

The research on learning from an firm-level perspective has its foundations on the work by March and Simon and their co-authors (Levinthal and March, 1993; Levitt and March, 1988; March, 1991; Simon, 1991). For example, March (1991) discusses two forms of learning, exploration and exploitation. Exploration models of learning encompass "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" (March, 1991, p. 71). Exploitation models of learning would focus more on "refinement, choice, production, efficiency, selection, implementation, execution" (March, 1991, p. 71). As it relates to the current study, previous experience may tend to favour exploitation of past knowledge, and therefore managers that devote resources to improving current processes and routines cannot devote the same resources toward exploration.

Within competitive environments, financial performance may depend on the learning ability of the firm. Baker and Sinkula (1999a, p. 296) define a learning orientation as "the degree to which firms are committed to systematically challenging the fundamental beliefs and practices" regarding their business and the environment in which it operates. As the nature of competition changes, successful firms will be those that are better able to become aware of the changes and that can acquire the resources and capabilities needed to compete. This may mean seeking information from different sources than those used previously, which may require information seekers to challenge their own assumptions regarding the information, as well as its applicability to their specific situation.

To this end, Slater and Narver (1995) suggest that the learning orientation of the firm may be the only driver of sustained competitive advantage as rival firms may be able to imitate other sources of advantage. In an agricultural context, Bone *et al*. (2003) found that managerial attitudes and attendance at educational workshops were important factors in farm performance in a sample of Australian farmers. Furthermore, Napier and Nell (2007) find that successful farmers are using new technologies and modifying business practices to remain successful in an increasingly competitive environment. This is not possible without continuous learning on new technologies and markets. Finally, researchers have begun to use the balanced scorecard approach, which focuses on continuous learning, as a means to assess performance within agricultural systems (Lourenzani, Queiroz and de Souza Filho, 2005; Shadbolt, 2005).

3. Methodology

This research utilizes non-hierarchical cluster analysis using the two-stage clustering method within SPSS (version 21.0). Cluster analysis is a statistical method that uses data of heterogeneous firms to create several homogeneous subgroups. For example[2], previous studies have used cluster analysis to assign members to clusters according to their use of meetings and extension (Rosenberg and Turvey, 1991), their view of themselves as entrepreneurs (Vesala and Vesala 2010), extensiveness of livestock systems (Usai *et al*., 2006) and animal husbandry practices (Kiernan and Heinrichs, 1994). Additionally, researchers in the management and marketing literatures have clustered firms by market orientation strategies (Gellynck *et al*., 2012; Greenley, 1995), innovativeness (Hollenstein, 2003) and knowledge management practices (Zack, McKeen and Singh, 2009).

Data for this paper come from responses of managers of beef operations to a questionnaire on managerial culture on beef farms in Illinois. The sampling frame (n=1569) was based on a mailing list of members of the Illinois Beef Association in 2007. In total, respondents operating cow-calf herds and feeding out steers and heifers returned 347 usable questionnaires. This study uses responses from 237 cow-calf producers in Illinois in order to focus the research on one particular segment within the beef value chain.[3] Respondents in the cow-calf sub-sample (n=285) are on slightly older than the average farmer in Illinois (68 years of age versus U.S. average of 57 years of age) (USDA -- National Agricultural Statistics Service, 2007) and have managed their operations for an average of 31.45 years. The sample demographics are in line with general demographics of beef production in the U.S., where over 30% of beef cattle farms are operated by farmers over 65 years of age (USDA -- National Agricultural Statistics Service, 2007). Cow-calf producers in the sample operate farms that are on average 942 acres and with herd sizes that average 69 animals.

The survey asked managers to rate their level of agreement with questions that related to their level of market orientation, innovativeness, performance, and the learning orientation of the firm, and provided definitions where appropriate. Additionally, the survey asked respondents how long they have been managing their operation.[4] Measurement scales were anchored with strongly agree (Strongly Agree =6) and strongly disagree (Strongly Disagree =1), with the neutral response removed. To limit 'straight lining' the survey, some items were negatively phrased. In these cases, disagreeing would imply agreeing with a positively phrased item[5]. To measure the market orientation of the respondent, the survey included 19 items from Narver and Slater's (1990) market orientation scale. Slater and Narver (1995, p. 67) define a market orientation as "the culture that (1) places the highest priority on the profitable creation and maintenance of superior customer value while considering the interests of other key stakeholders; and (2) provides norms for behaviour regarding the organizational development of and responsiveness to market information." Their measurement scale, therefore, examines the degree to which firms are aware of customer needs and competitor responses, as well as how managers utilize this information within the firm. To measure commitment to learning, the survey included three items from Sinkula, Baker and Noordewier's (1997) learning orientation scale. This scale examines the view that learning is an investment that the firm can deploy to achieve certain advantages in the market as well as the need to question assumptions the firm makes about the market in which they operate. A scale developed by Hurley and Hult (1998) was included to measure firm innovativeness. For the purposes of this study, innovation is broadly defined as a change in routine (Nelson and Winter, 1982), and therefore innovativeness is thought of as a firm's willingness to pursue change in the organization. The innovativeness scale asked farm managers to rate their level of agreement with different items that examined the penchant for managers to utilize innovative strategies to solve problems on the farm. Finally, satisfaction with farm performance was measured using six subjective indicators. We use subjective performance as opposed to objective measures of performance as our sample consisted of small, privately held businesses that are generally unwilling to share confidential financial data, even in an anonymous setting. While self-rated scales may introduce bias to the results, this has been shown to be limited in surveys where the respondent is anonymous (Nederhof, 1985). Furthermore, research has shown that subjective scales are correlated with their parallel objective measures (Richard, Wu and Chadwick, 2009; Wall *et al*., 2004). Appendix A displays the survey items as well as reliability statistics.

4. Results

Figure 1 and Table 1 display the result of the cluster analysis. Using two-step clustering, four clusters emerge from the data. The distribution of firms across clusters is uniform and the ratio of largest cluster to smallest cluster is only 1.49 (119/80). Cluster 1 consists of 80 firms that have more than 17 years of experience but have the highest learning scores (are more likely to strongly agree with statements) as their average summated score for the five-item learning orientation scale is 20.46. This cluster seems to consist of firms who are relatively new to beef production and want to move quickly along the learning curve. Cluster 2 consists of

[2] This list is non-exhaustive.

[3] In total, 285 respondents were involved in cow-calf production. I removed cases from the dataset if manager age minus managerial experience was less than 10. Low or negative scores indicate a misunderstanding of the experience question, which is an important component of this research.

[4] The actual question was, "How many years have you produced cattle on your farm?"

[5] To allow for comparison with other items, negatively phrased items were reverse coded so that a score of 1 on a negatively phrased item would be akin to a score of 6 on a positively phrased item.

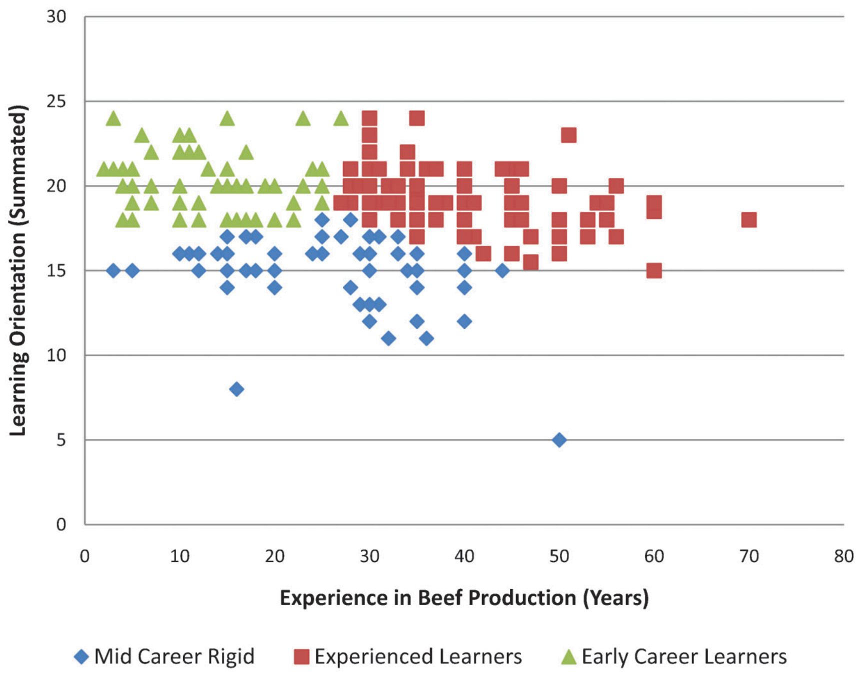

Figure 1: Scatter plot of managerial experience and learning orientation

119 firms that on average have almost 45 years of experience in beef production along with a high summated learning orientation score (average of 18.52). This cluster seems to contain firms that are quite experienced and see learning as a valuable resource in terms of keeping up with industry trends. Cluster 3 consists of 86 firms with an average of just over 26 years of experience in beef production but the lowest learning orientation scores (average summated score is 14.97).

Table 1: Differences in cluster inputs and farm characteristics across clusters (standard deviation in parentheses)

	Cluster			
Variable	**Early Career Learners (1)**	**Experienced Learners (2)**	**Mid-Career Rigid (3)**	**F-Test**
Experience (*Years*)	13.44	39.99	25.45	167.835***
	(6.90)	(9.59)	(9.99)	
Learning Orientation (*Summated Scale*)	20.23	18.96	15.13	136.689***
	(1.78)	(1.88)	(2.13)	
Learning Orientation Items				
The basic values of this farm include learning as a key to improvement.	5.26	5.04	4.04	67.401***
	(0.57)	(0.65)	(0.79)	
Our take is that learning is an investment, not an expense.	5.45	5.10	4.18	50.297***
	(0.53)	(0.78)	(0.95)	
Learning on my farm is seen as a key commodity necessary to guarantee survival.	5.45	5.06	4.28	40.227***
	(0.50)	(0.83)	(0.93)	
Not afraid to challenge assumptions about customers.	4.98	4.54	3.54	56.289***
	(0.71)	(0.77)	(0.99)	
How perceive marketplace must be continually questioned.	4.53	4.29	3.37	33.592***
	(0.90)	(0.89)	(0.94)	
Herd Size (*Cows and Calves*)	84.11	134.03	130.92	1.832
	(102.72)	(179.16)	(195.38)	
Farm Size (*Acres*)	567.84	1073.18	918.13	3.307*
	(709.69)	(1527.35)	(1052.14)	
Age of operator (*Years*)	46.69	61.59	52.92	44.949***
	(12.43)	(9.59)	(8.51)	
Education#	4.13	3.65	3.89	2.489
	(1.27)	(1.38)	(1.37)	
Number of cases	62	99	76	

Notes: #: 1=Some high school, 2=High school graduate, 3=Some college, 4=Vocational/Tech degree, 5=College graduate, 6=Graduate degree.
In this and following tables, ***, **, * signify significance at the 0.001, 0.01, and 0.05 levels, respectively.

Table 2: Means of market orientation, innovativeness and performance across clusters

Variable	Cluster			F-Test
	Early Career Learners (1)	Experienced Learners (2)	Mid-Career Rigid (3)	
Customer Orientation (Summated)	12.52[a]	11.76[a]	10.13[b]	12.685***
Competitor Orientation (Summated)	26.60[a]	26.83[a]	23.22[b]	7.344***
Coordination (Summated)	16.15[a]	16.17[a]	13.79[b]	10.964***
Innovativeness (Summated)	25.65[a]	23.59[b]	22.17[c]	19.301***
Performance (Summated)	23.49[ab]	24.08[a]	22.25[b]	3.053*

Notes: Within rows, means that share superscripts are not significantly different at the 0.05 level of significance. Summated scales are calculated by summing individual items from measurement scales. Refer to Appendix A to see the actual items.

As the learning orientation input variable was a summated scale, meaningful differences across learning scores are not obvious. Firms in Cluster 1 (termed 'Early Career Learners') have the highest scores on each item while firms in Cluster 3 (termed 'Mid-Career Rigid') have the lowest scores. Firms in cluster 2 (termed 'Experienced Learners') had the second highest scores across learning items. In terms of other characteristics, manager age is significantly different across clusters, while herd size and number of acres operated are not significantly different. Highest level of education received is not significantly different across clusters.

After firms were assigned into clusters, comparisons of market orientation, innovativeness, and performance scores were conducted using one-way ANOVA (Analysis of Variance). Table 2 displays the results of this comparison. In line with results from previous studies (Baker and Sinkula, 1999b; Farrell, Oczkowski and Kharabsheh, 2008), firms that have higher learning orientation scores also have higher scores on market orientation, organizational innovativeness, and performance. It is interesting to note that significance between scores seems to relate more to the learning orientation of the firm than on the level of experience. Firms in Cluster 3 (Mid-Career Rigid) appear to be significantly different from firms in the other clusters in terms of market orientation, innovativeness, and satisfaction with performance. Young firms with higher learning orientation scores (Cluster 1) appear to be somewhat more innovative than more experienced firms and those not as committed to learning (Clusters 2 and Cluster 3).

Table 3 displays mean scores from each cluster on individual items comprising the market orientation scale. Firms in Cluster 1 (Early Career Learners) are

Table 3: Means of market orientation items across clusters

Variable	Cluster			F-Test
	Early Career Learners (1)	Experienced Learners (2)	Mid-Career Rigid (3)	
Customer Orientation Items				
Discover customer needs	4.31[a]	3.98[a]	3.49[b]	9.109***
Incorporate solutions in products	4.23[a]	3.80[b]	3.43[b]	9.177***
Work with lead customers	3.98[a]	3.97[a]	3.21[b]	10.238***
Competitor Orientation Items				
Share information about competitors	3.86	3.96	3.55	2.032
Discuss competitor strengths and weaknesses	4.05	3.80	3.55	2.786
Target customers where have competitive advantage	4.39[a]	4.31[a]	3.62[b]	9.649***
Collect information on competitors	3.23	3.27	2.84	2.504
Diagnose competitor goals	3.10[ab]	3.26[a]	2.71[b]	4.110*
Identify where competitors have succeeded or failed	4.11[a]	4.18[a]	3.50[b]	7.784**
Evaluate strengths and weaknesses of competitors	3.87[ab]	4.04[a]	3.45[b]	5.270**
Coordination Items				
Regularly visit customers	3.48[ab]	3.64[a]	3.00[b]	4.438*
Discuss experiences with partners	3.95	4.15	3.82	1.499
Business units work together to serve customer needs	4.19[a]	3.98[a]	3.36[b]	10.744***
Understand how we contribute to customer value	4.52[a]	4.41[a]	3.62[b]	15.270***

Notes: Scores are averages of all firms in cluster. Items were anchored with 1=strongly disagree and 6=strongly agree. Within rows, means that share superscripts are not significantly different at the 0.05 level of significance.

Table 4: Means of innovativeness and performance items across clusters

Innovativeness and Performance Items	Cluster: Early Career Learners (1)	Experienced Learners (2)	Mid-Career Rigid (3)	F-Test
Innovativeness Items				
Technical innovation accepted	4.97[a]	4.52[b]	4.16[c]	12.433***
Seldom seek innovative ideas#	5.16[a]	4.60[b]	4.24[b]	12.726***
Innovation accepted	4.95[a]	4.48[b]	4.17[b]	13.657***
Penalized for new ideas that fail#	5.40	5.27	5.03	2.712
Innovation is risky#	5.16[a]	4.73[b]	4.58[b]	5.212**
Performance Items				
Return on farm assets did not meet expectations#	3.65	3.88	3.63	1.055
Satisfaction with overall performance	4.18[ab]	4.27[b]	3.80[a]	4.341*
Return on production investments	4.21	4.16	3.89	2.006
Cash flow was not satisfactory#	3.68	3.94	3.72	1.053
Return on marketing investments	4.15	4.09	3.87	1.609
We receive higher prices than competitors	3.85	3.59	3.54	1.773

Source: Author calculations

Notes: Items with # were reverse coded. Scores are averages of all firms in cluster. Items were anchored with 1=strongly disagree and 6=strongly agree. Within rows, means that share superscripts are not significantly different at the 0.05 level of significance.

more likely to strongly agree with items that examine how these firms provide solutions to meet market needs. In terms of using competitors as a source of market information, firms in Cluster 2 (Experienced Learners) are more likely to agree with the use of competitors as a source of market information, specifically whether they try to determine which competitor strategies were successful or to evaluate relative strengths and weaknesses of other firms in the industry. Differences across high and low learners (Clusters 1 and 2 versus Cluster 3) emerge when examining how firms use the information gathered from customers and competitors. Firms in Cluster 3 are less likely than other firms to agree with items that measure if business units work together to create customer value and if employees understand how the firm creates value for downstream partners. Firms in Cluster 3 are also less likely to understand how their actions contribute to customer value.

Table 4 displays scores on individual items that measure innovativeness and the manager's satisfaction with performance. Firms in Cluster 1 (Early Career Learners) were more likely to agree with items that measured their willingness to accept technical innovation and were less likely to agree that innovation is risky.[6] While they were different in terms of summated scores, firms in Cluster 2 (Experienced Learners) and Cluster 3 (Mid-Career Rigid) were not statistically different in terms of their responses to the individual items measuring innovative activities.

While the summated performance score was significantly different across clusters, differences among individual items were not significant in five of the six items. The analysis shows the only statistically significant difference occurs in satisfaction with overall performance. Firms in Cluster 2 (Experienced Learners) were more satisfied with overall performance than firms in Cluster 3 (Mid-Career Rigid).

[6] Question was negatively phrased and reverse coded in data analysis.

5. Discussion

The goal of this research was to examine how a firm's learning orientation and managerial experience relate to firm innovativeness and satisfaction with performance. Using a two-step cluster analysis, three clusters emerged using years of managerial experience and a summated learning orientation scores as inputs. Cluster 1 consisted of firms that averaged over 17 years' experience and higher learning orientation scores. Firms in Cluster 2 were experienced in beef production as they averaged almost 45 years of experience in beef production, and had the high scores on learning orientation items. Cluster 3 consisted of firms that averaged over 26 years of experience in beef production and the lowest learning orientation scores. Mangers in Cluster 1 and Cluster 3 are of similar age (47 versus 51 years of age) and have similar levels of experience (17 versus 26 years). Given these averages and differences in learning orientation, it is possible that managers in Cluster 1 have had a prior career that is influencing their approach to beef production. Interestingly, no cluster emerged that consisted of firms that had high experience and low learning scores. This may be due to survivor bias as firms that do not view learning as a key to survival may have already exited the industry.

One-way ANOVA analysis revealed that scores on market orientation, innovativeness and performance items were significantly different across clusters. Firms that were more likely to agree with the items assessing learning orientation, that is, those with higher scores on learning orientation items, also had higher scores for items that measured the level of market orientation, innovativeness and performance. This result is in line with prior studies that suggest the that a learning orientation and a market orientation are antecedents of innovativeness (Baker and Sinkula, 2002). This finding may also corroborate the findings of Wilson *et al.* (2001) who find that farms with more experience also exhibit higher levels of technical efficiency. Perhaps the increase in efficiency is the result of the willingness of these farms to challenge the status quo and their willingness to adopt new technologies.

Policy makers interested in helping beginning farmers improve financial performance may look to replicate models that highlight new technologies and may make it easier for managers to observe how other firms operate. For example, exemplary programs such as demonstration farms (Pangborn, Woodford and Nuthall, 2011) and the Beef Profit Partnerships model that has been successful in Australia and New Zealand (Clark *et al.*, 2007) may increase the adoption of best practices and improve the viability of small and beginning farms. While these resources are valuable as learning tools for farm managers, they also provide managers with an opportunity to discuss farming practices with other farm managers and practitioners who have a different perspective. This is important as research has shown that knowledge transfer is more likely to occur when firms are similar in terms of strategies employed and customers served (Darr and Kurtzberg, 2000). The source of information is also important, as Sligo and Massey (2007) find that farm managers may place more trust in the information coming from university personnel and other farmers as opposed to sales personnel who may be only concerned with making a sale.

This study is not without its limitations. First, the study relies on survey responses from managers of beef farms in Illinois to examine the relationship between learning orientation and managerial experience. The relatively narrow dataset may limit the ability to extrapolate these results across countries or commodities. Furthermore, as the data is cross-sectional, the study did not examine direction of causality between a commitment to learning and innovativeness and performance.

Even with these limitations, these findings corroborate the results from recent research on factors affecting performance of SMEs outside of agriculture that found that managers who emphasize continual learning are more innovative and have better performance (Real, Roldán and Leal, 2012; Rhee, Park and Lee, 2010). Moreover, the results presented here may be especially important to small and beginning farms that may not have the benefit of previous experience from which to draw upon when they face challenges. These results may therefore signal a need to refocus attention on methods that increase the learning orientation of producers. Given the evolving nature of the agricultural industry and the effects globalization and consolidation are having on competition for inputs and market access, firms who invest in the resources that enable them to recognize opportunities may be successful moving forward. Conversely, firms that do not stay abreast of these changes may find themselves unable to compete with firms that have already made significant investments in time and money in building a learning orientation. Future research could examine how agricultural firms that operate at some distance from the final consumer develop and foster a culture of learning. As both March (1991) and Simon (1991) suggest that organizational learning is a social construct, future work addressing the social aspect of a firm's learning orientation would provide much needed information.

Additionally, future research could examine where agricultural firms with a learning orientation acquire information. Historically, farm consultants have played an important role in the provision of market information and strategic planning to primary agriculture. More technologically adept farmers may find that supplementing that service with information from social media platforms (i.e. Twitter, Facebook, LinkedIn, and YouTube) is also beneficial as it provides a low-cost method to access information from a broader network of providers. Through social media, producers can participate in discussions where participants share their views and experiences on production and management issues. As these discussions may include participants located all over the world, farmers receive an antidote for structural and cognitive rigidity, which can limit innovativeness.

About the author

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Appendix A: Measurement items

Measurement Items	Mean	Standard Deviation	Item-to-Total Correlation
Learning Orientation (Alpha=0.837)			
(Sinkula, Baker and Noordewier, 1997)			
The basic values of this farm include learning as a key to improvement.	4.76	0.891	0.642
Our take is that learning is an investment, not an expense.	4.88	0.968	0.639
Learning on my farm is seen as a key commodity necessary to guarantee survival.	4.89	0.960	0.685
We are not afraid to challenge assumptions we have made about our customers.	4.30	1.055	0.499
Personnel on this farm realize that the very way they perceive the market must be continually questioned and adapted.	4.04	1.040	0.378
Customer Orientation (Alpha=0.802)			
(Narver and Slater, 1990)			
We continuously try to discover additional customer needs which they are not aware of yet.	3.94	1.199	0.698
We incorporate solutions to unstated customer needs in our new products and services.	3.80	1.134	0.658
We work closely with lead customers and try to recognize their needs months or even years before the majority of the market may notice them.	3.75	1.238	0.592
Competitor Orientation (Alpha=0.870)			
(Narver and Slater, 1990)			
Employees on our farm share information concerning competitor activities.	3.81	1.366	0.580
We regularly discuss competitor strengths and weaknesses	3.75	1.241	0.628
We target customers where we have an opportunity for competitive advantage.	4.11	1.239	0.540
Members of our farm collect information concerning competitor activities.	3.15	1.332	0.679
We diagnose competitor goals.	3.06	1.286	0.713
We identify the areas where our competitors have succeeded or failed.	3.95	1.225	0.665
We evaluate the strengths and weaknesses of key competitors.	3.78	1.263	0.721
Coordination (Alpha=0.740)			
(Narver and Slater, 1990)			
We regularly visit our current and prospective customers.	3.39	1.468	0.506
We freely discuss our successful and unsuccessful customer experiences with our partners.	3.99	1.277	0.465
All of our business units (marketing, production, research, finance/accounting) are integrated in serving the needs of our target markets.	3.84	1.198	0.610
People on our farm understand how everyone can contribute to creating customer value.	4.16	1.167	0.571
Innovativeness (Alpha=0.712)			
(Hurley and Hult, 1998)			
Technical innovation based on research results is readily accepted.	4.50	1.020	0.477
We seldom seek innovative ideas which we can use on our cattle operation.[#]	4.63	1.148	0.539
Innovation is readily accepted in our beef operation.	4.52	0.942	0.529
Individuals on our farm are penalized for new ideas that don't work.[#]	5.20	1.020	0.297
Innovation in our farm is perceived as risky and is resisted.[#]	4.77	1.118	0.520
Performance (Alpha=0.819)			
The return on farm assets did not meet expectations last year.[#]	3.73	1.328	0.656
We were very satisfied with the overall performance of the farm last year.	4.07	1.153	0.710
The return on production investments met expectations last year.	4.07	1.092	0.756
The cash flow situation on the farm was not satisfactory.[#]	3.77	1.312	0.559
The return on marketing investments met expectations last year.	4.02	1.041	0.624
The prices we receive for our product is higher than that of our competitors	3.69	1.101	0.249

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Structuring the problematic situation of smallholder beef farming in Central Java, Indonesia: using systems thinking as an entry point to taming complexity

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ABSTRACT

Improving smallholders' performance remains a seemingly intractable central issue for beef farming development in Indonesia. Studying a complex system such as beef farming requires a systemic approach. This paper reports on the combined use of three complementary systems approaches to structure and subsequently model the problem situation as the first research step towards seeking effective solutions. System Dynamics (SD) is considered to be a powerful methodology for taming the complexity of a system. However its problem identification stage has been criticized as being insensitive to the multiple interests and power structures likely to occur in a smallholder system. This study aimed to explore the possibility of combining Soft System Methodology (SSM) and Critical System Heuristics (CSH) to overcome that limitation and accommodate multiple perspectives including smallholder views on system improvements. A series of interviews and workshops involving 2 farmer groups was undertaken in Central Java, Indonesia. The benefits of inclusion of CSH in the research protocol included its ability to embrace the opinions of the less-powerful stakeholders - the farmers. Thus, for the stakeholders, it provides a better understanding of the system than provided by a combination of SD and SSM, and thereby the potential for facilitating development of more effective interventions.

KEYWORDS: Multi methodologies; System Thinking; Soft System Methodology; CATWOE analysis; Critical System Heuristics

1.Introduction

Beef Farming in Indonesia

The imbalance of beef supply and demand is a crucial issue for agricultural development in Indonesia. In the decade to 2012 the cattle population increased from 11.1 to 14.8 million animals (DGLVS, 2012). However, beef demand was also increasing due to a combination of population growth of 1.49% per annum (Rahayu, 2011), and increasing per capita consumption of animal-protein sourced products, including beef (Darajati, 2009; Fabiosa, 2005; Pingali, 2007). Although many government programs have been introduced to boost the Indonesian cattle population, in 2012 Indonesia still imported 283,000 of live cattle, equal to 51,000 tons of carcass, and 34,000 tons of frozen beef. In total, this comprised 17.5% of the national consumption (Director General for Livestock and Veterinary Services, 2012).

Smallholder beef farming

Improving smallholder performance is the key to developing Indonesia's beef industry (Hadi *et al.*, 2002). With a typical farm size of 1–4 cattle/farmer, there are more than 4 million beef-farming households in Indonesia (Boediyana, 2007). Zero-grazing is the common feeding strategy. Cattle are kept in sheds and farmers cut grass from forests, fallows, rangelands, roadsides, wastelands, and post-harvest cultivated areas (Devendra and Sevilla, 2002). For smallholders, cattle are not merely a source of income, but are also a valuable asset (Patrick *et al.*, 2010), a wealth status indicator, and an economic buffer for the household (Huyen *et al.*, 2010; Stroebel *et al.*, 2008; Dovie *et al.*, 2006; Siegmund-Schultze *et al.*, 2007).

As part of an agricultural system, smallholders have intense interconnectedness both within their own households and to the wider community (MacLeod *et al.*, 2011). Smallholder farming involves not just biophysical,

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but also social, ecological, political and economic elements (Snapp and Pound, 2008; Tavella *et al.*, 2012). In addition, as demonstrated by Hounkonou *et al.*, (2012), smallholders engage with a wide variety of actors whose interests are varied. Acknowledging these varied interests is an important aspect of a successful development strategy (Binam *et al.*, 2011; Drafor, 2011; Kaufmann, 2007).

In the developing world, smallholder groups are typically characterized by the occurrence of power asymmetry, a condition where some people or groups of people are more favored and have dominance over others who are marginalized (Ayittey, 2006; Hounkonnou *et al.*, 2012). In cultural terms, a common aspect of Indonesian society is the existence of a social hierarchy in which asymmetrical power relations are common, leadership styles are mostly top-down, and communication is indirect, averting direct negative feedback (Hofstede, 2001). Thus, dealing with smallholders requires an approach which is sensitive to this power inequality.

This paper reports on part of a research program focused on developing strategies to improve smallholder beef farming in Central Java, Indonesia. The target population is the farmer groups which received aid through the *Graduates Support Farmers Program* - one of the major programs specifically designed to promote cattle breeding to support national beef self-sufficiency. Each group is assisted by a university graduate in animal or veterinary science.

Systems thinking methodology

Systems thinking emerged for dealing with complex problems (Maani and Maharaj, 2004; Kapsali, 2011) which provides a framework for seeing dynamic interrelationships and patterns of change as *a whole* (Senge, 1992). Senge uses a simple metaphor to explain the importance of seeing things as a whole: "Dividing an elephant in half does not produce two small elephants" (Senge, 1992). A system is more than the simple sum of its parts and dividing them will often result in incomplete and irrelevant outputs.

System Dynamics (SD) is considered to be an important methodology in systems thinking because it has the power to build a rigorous model which represents the dynamics of the real situation (Jackson, 2002; Rabbinge *et al.*, 1994; Rodriguez-Ulloa and Paucar-Caceres, 2005).

The entry point of SD is problem identification, known as "*problem structuring*" (Maani and Cavana, 2007; Maani and Cavana, 2002; Sterman, 2000). This is an important step to justify and clarify the purpose of the whole SD process. However, at this stage of SD it is considered to have limitations because it tends to neglect the stakeholders' interests, which are likely to be varied (Rodríguez-Ulloa *et al.*, 2011; Lane and Oliva, 1998), as well as being insensitive to power structure issues (Jackson, 2002). These limitations will be exacerbated when dealing with smallholder farming which typically exhibits both issues.

Soft System Dynamics Methodology (SSDM) which combines SD with Soft System Methodology (SSM) is one of the approaches that has emerged to overcome these limitations of SD (Rodriguez-Ulloa and Paucar-Caceres, 2005). SSM is regarded as being sensitive to multiple stakeholders' interests (Hardman and Paucar-Caceres, 2011) although it has been criticized for lacking sensitivity to power structures (Mingers, 2000; Flood, 2000). SSDM employs two main features of SSM; *the rich picture* and *the CATWOE analysis*.

Typically, a rich picture is a cartoon-like summary of the system which describes diagrammatically the main variables and issues involved in the system. The CATWOE (Customers, Actors, Transformation, World-view, Owner, and Environment) analysis helps to define how human activity contributes to the problematic system, and subsequently develop a *root definition of the system* (Checkland and Poulter, 2006; Maani and Cavana, 2007; Wilson, 2001), "a concise, tightly constructed description of a human activity system which states what the system is" (Checkland, 1999). Both tools are intended to make it easier for all stakeholders to 'see' the problem and therefore encourage them to be more 'involved' in the process of structuring the problem (Checkland and Poulter, 2006). This is where SSM is considered to be sensitive to multiple stakeholder perspectives (Jackson, 2002).

As mentioned above, despite this advantage, SSM has also been criticized for being insensitive to power structures (Mingers, 2000; Flood, 2000). In order to deal with the distortions introduced by power asymmetries in the target groups, this study complemented SSDM by incorporating aspects of Ulrich's Critical System Heuristics (CSH) (Ulrich and Reynolds, 2010; Ulrich, 1983). CSH is considered to provide enhanced sensitivity to the societal power issue, even in certain coercive situations (Flood and Jackson, 1991; Reynolds, 2007; Jackson, 2003) through its use of 12 boundary critique questions, each asked, in *is* and *ought* mode. System stakeholders are asked to respond to these questions, usually in separate iterations of interviews or focus groups, to contrast what the system currently *is* with what it *ought to be* (Flood and Jackson, 1991; Midgley, 2000), as presented in Table 1. Such a process enables system designs or proposed designs to be carefully interrogated as to their partiality and also provides criteria for debate between stakeholders, including not only those involved in systems design but also those affected by the designs but not involved (Jackson, 1991).

This paper proposes an approach to enhancing the problem structuring stage of the SD approach, as a way to ensure development of better outcomes. It employs a combination of both SSM and CSH frameworks in an effort to provide methodology which is able to produce a rigorous model that not only acknowledges the multiple perspectives of different stakeholders but is also sensitive to social power structures. Such methodology is required to study the problematic situations of the smallholder as the initial step in developing appropriate interventions.

2. Methodology

The study took place within 2 purposively-selected farmer groups in Central Java, a major beef producing province in Indonesia. Both groups had been participating in the *Graduates Support Farmers Program*, but with disappointing results. Despite the program focus on

Table 1: CATWOE questions of SSM

No	Element	Question
1	Customers	Who are the system beneficiaries?
2	Actors	Who transforms inputs to outputs?
3	Transformation	What transformations exist?
4	Worldview	What is the reason for this transformation?
5	Owners	Who can stop or change this transformation?
6	Environment	What constraints are there in the immediate surroundings of this transformation?

Source: (Checkland, 1999; Checkland and Poulter, 2006).

improved breeding performance, results to date included a long calving interval (>500 days) with a very low (3%) rate of second calving (Yuwono and Sodiq, 2010). Consequently, farmers had suffered losses rather than improved productivity and financial outcomes (Sodiq, 2011).

Clearly, there were problems involved. However, it is not easy to define *the problem* without oversimplifying the situation, as farmers thought that they were conducting their farming routines as usual. Therefore, instead of defining the problem, this study tried to explore *the problematic situation*, defined as an uncomfortable situation which provokes people to think that something needs to be improved (Checkland and Poulter, 2006). The problematic situation was then structured as an input to determine proper intervention strategies.

Four stages of field study were undertaken to explore and structure the problematic farming situation. This was commenced by conducting interviews with all actors involved, followed by a workshop to confirm the findings. Then a further set of interviews was undertaken to map the problematic situation. Finally, another workshop was performed to finalize the results. The methodological steps of the research are presented in Figure 1.

Expressing the flux of everyday farming

This stage was aimed to capture the current farming situation. It commenced by conducting a meeting with the farmer groups' representatives to gain mutual understanding among researcher and participants with regard to the objectives and the approaches of the study. Canvassing farmers' perspectives from an early stage was aimed at building farmers' sense of being acknowledged; this was expected to endorse future cooperation. Additionally, elaborating perspectives of farmers and other identified actors was expected to create a situational understanding that the problem was as identified by stakeholders, not researchers, and the action objective selected was defined and desired by them, thereby encouraging participation (Checkland and Poulter, 2006).

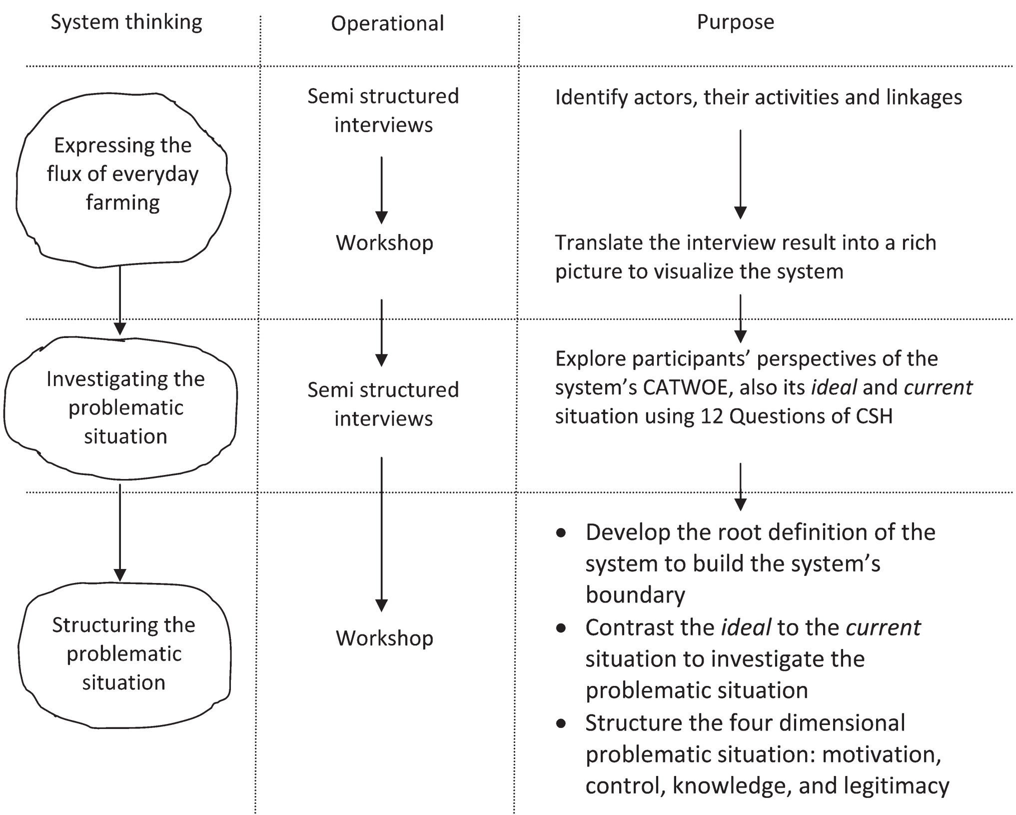

Figure 1: Methodological steps

The next activity was a series of semi-structured interviews undertaken with all farmers in the two selected groups. The open nature of semi-structured interviews ensured the participants were free to express their opinions without any structural interference from the researcher (Checkland, 1999). However, as points of reference for interviewees the researcher set three elements to be identified: *the actors*, *the activities* and their *linkages* in the system. As a result, in addition to farmers and their households, 4 other actor groups were identified: university researchers; livestock service officers; cattle traders; and the program coordinator. These identified actors were then interviewed to enrich the perspectives.

Following the interview series, a workshop involving farmers, graduates, extension agents, cattle traders, and the program coordinator was conducted for each group to develop the rich picture. The workshop took place in the residence of one of the farmers, so that participants would feel at ease in familiar surroundings.

The list of actors obtained from the interviews was presented on a poster-sized paper for discussion by the participants. Afterwards, based on findings from the interviews, a diagram of the linkages among actors and their activities was drawn by the researcher as a draft of the rich picture. This draft was then critiqued by all participants to ensure that it best-represented the real world situation.

Investigating the problematic situations

Another series of semi-structured interviews of the same participants was then conducted to explore participants' perspectives on the situation considered as problematic. At this stage, SSDM used the CATWOE questions of SSM to harness the problematic situation of the system (Rodríguez-Ulloa *et al.*, 2011). However, this study complemented the CATWOE questions with the 12 boundary critique questions of CSH to investigate whether CSH was able to enhance the CATWOE analysis and how its sensitivity to power asymmetry was able to assist participants to identify problematic situations.

The interviews started with the CATWOE questions of SSM (Checkland, 1999; Checkland and Poulter, 2006) (Table 1).

This was followed by the 12 boundary critique questions of CSH (Ulrich, 1983) (Table 2). To make it easier for the participants, the 12 questions were first posed in the "ought to be" mode (Ulrich and Reynolds, 2010), following the recommended question sequence by Reynolds (2007). During interviews, the rich picture was displayed for reference.

Structuring the problematic situations

The results of the interviews were then collated and listed by the researcher for discussion at the second workshop to structure problematic situations. There were three phases. In the first, the discussion was focused on CATWOE analysis to help develop the root definition of the system. The next phase consisted of discussion of the *is* and the *ought to be* modes of the CSH. Finally, the participants were asked to critique the gap between the actual and the ideal situation. During the discussion, the rich picture was also displayed for reference.

The gap critiques were then compiled by the researcher to build the structured problematic situation of beef farming in four dimensions: motivation; power control; knowledge; and legitimacy (Ulrich and Reynolds, 2010). Finally, in consultation with key informants, variables which seem to drive the problematic situations were investigated.

3. Results

Current farming activities

Figure 2 presents the translated version of the original rich picture developed in the workshop. Diagrammatic visualization is important, because it can portray simply but effectively how the system works (Salles and Bredeweg, 2006; Salles *et al.*, 2006). Furthermore, visualization encourages learning more so than equations or numbers (Mayer *et al.*, 1996; Moreno *et al.*, 2011).

The rich picture developed depicts the system at farm-household and community level (McConnell and Dillon, 1997). A total of 5 actors were identified to have a relationship with the group's farming activity: university; government; peer-farmers; cattle traders; and farmer households. The role of each actor is presented in Table 3.

At the household level, all farmers in both groups had rice plantations; these ranged in area from 1,250–12,500 m^2, with a mean of 2,830 m^2. Almost 75% of them had a farmed fish pond (average size 288 m^2); and 32% of them had a fish pond and a rice plantation. All these activities were conducted by the household head, because fewer than 25% of farmers in each group made use of family labor. However, they could employ casual workers whenever needed, usually during planting, weeding, and harvesting.

At the broader level of community system, these farm households were connected into a broader group activity of beef farming. As a system, beef farming in both groups was linked to farm-households for supplying labor and rice straw. In return, beef farming supplied households with cash and manure, either for fish ponds or for cropping. River banks and forest margins were the two main locations where farmers could collect forage for their cattle.

Problematic situation

The second interview series provided inputs for the workshop session designed to identify and structure the problematic beef farming situation. Results of the CATWOE analysis from the workshop are presented in columns 1 and 2 in Table 4. Following Checkland's SSM (Checkland, 1999), the root definition of the system was formulated as follows:

> *"A farmers' group-owned system which, under the constraints of feed availability, price uncertainty, lack of access to markets, and unfavorable pricing policy, receives government grant assistance and transforms cattle into cash through raising cattle, mostly by fattening. The transformation is carried out by farmers, and directly affected by cattle traders, farmers' household members, and the government. The worldview behind this transformation is to generate additional revenue to the farmers' household"*

Table 2: The 12 boundary critique questions of CSH

No	Element	Question (*is* and *ought* mode)
1	Beneficiaries	Who *are/ought to be* the actual beneficiaries of the system, i.e. belong to the group of those whose interest and values are served?
2	Purposes	What *is/ought to be* the actual purpose of the system?
3	Measure of success	What *are/ought to be* the system's measures of success?
4	Decision maker	Who *is/ought to be* the decision maker, i.e. in control of the conditions of success of the system?
5	Resources	What resources *are/ought to be* under the control of the system?
6	Decision environment	What conditions of success *are/ought to be* outside the control of the system decision maker?
7	Expert	Who *are/ought to be experts* i.e. who provides relevant knowledge and skills for the system?
8	Expertise	What *is/ought to be* relevant knowledge and skills that should flow into the design of the system?
9	Guarantor	What or who *is/ought to be* the regarded as guarantor, providing assurance of successful implementation?
10	Witness	Who *are/ought to be* the witnesses, representing the interest of those negatively affected but not involved with the system?
11	Emancipation	What *are/ought to be* the opportunities for the interests of those negatively affected to have expression and freedom from the worldview of the system?
12	Worldview	What space *is/ought to be* available for reconciling differing underlying worldviews about design of the system among those involved and affected?

(Ulrich and Reynolds, 2010; Georgiou, 2012).

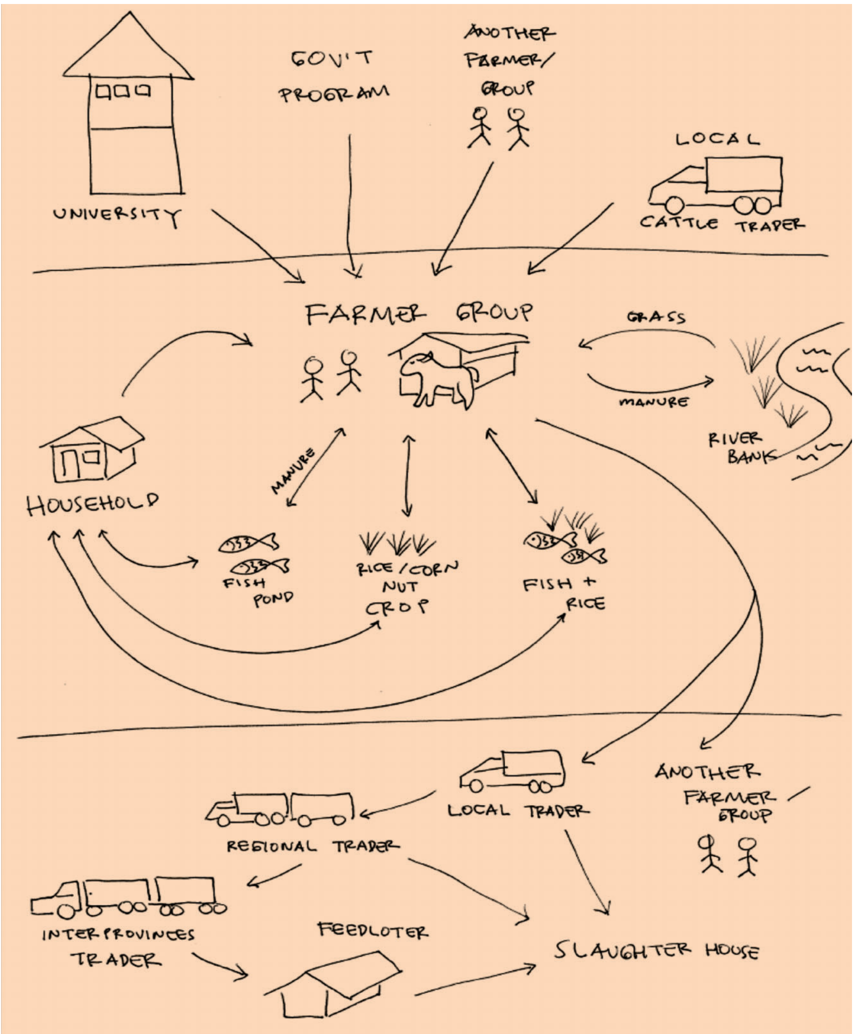

Figure 2: Rich picture of smallholder beef farming

Table 3: Actors of the beef farming system

No	Actor	Role
1	University (Faculty of Animal Science)	Provide expertise to improve farmer's knowledge and skills particularly on veterinary and feeding technology Give recommendations to farmer groups when applying for government program aid Manage the program implementation at the local level
2	Government	Extension services and artificial insemination
3	Peer-farmers	Including group leaders, are sources of information, knowledge and skills Buy or sell cattle from and to other peer farmers
4	Cattle traders	Provide stock whenever farmers need to buy cattle Buy and sell cattle
5	Farmers' household	Provide labor when required to help the household head to manage their resources

Transformation (T) is the core of the root definition encapsulating the concepts of the system. This transformation expresses any purposeful activities which "*change or transform some input into some output*" (Hardman and Paucar-Caceres, 2011). In this context, participants suggest that the transformation existing in their beef farming is "*raising cattle to generate cash*". The CATWOE analysis also identifies some problematic situations: feed availability, price uncertainty, lack of access to market, and unfavorable pricing, all of which potentially obstruct the transformation process.

The next step in the process, to deal with the situation where asymmetric power is likely to exist, as in the case of smallholder farmers, was to direct the workshop discussion into addressing the 12 questions of CSH (12Q CSH), in *ought* (ideal situation) and *is* (current situation) modes. When mapping the ideal conditions, participants were able to reach agreement without lengthy debate. It took longer to debate the real *is* conditions, because of the quite different perspectives held by different participants. The argument divided participants into 3 groups: Group 1 (comprising farmers, graduates, group leaders, and traders); Group 2 (the government representatives); and Group 3 (the *graduates support farmer* program coordinator).

The results of the CSH explorations are shown in Table 4, columns 3–6. To help in structuring the problematic situations, these elements of CSH were categorized into the 4 dimensions of motivation, knowledge, power structure, and legitimacy (Ulrich and Reynolds, 2010). As shown in Table 4, the 12Q CSH were able to expand the *actors* of CATWOE into three elements (*expert, expertise* and *guarantor*) and *transformation* into two elements (*purpose* and *measure of improvement*), thereby providing a richer description of the system. Moreover it also provided a basis to encourage discussion among participants, because it allows critiquing of the actual compared to the ideal situation. Disparity of responses on the *purposes*, the *measure of improvement*, and the *worldview* in the actual condition reflect that CSH was able to elicit farmers' views which differed from those of the government and the university.

Further, each of the dimensions was explored to find out what were the reasons behind these gaps between actual and ideal conditions (Figure 2). These sets of reasons allow the researcher to generate conceptual models as an input to develop the appropriate intervention model. Compared to SSM, the 12 boundary critique questions of CSH clearly provide a richer description of the problematic situation of smallholder beef farming (Figure 3) which is an entry point to taming its complexity.

4. Discussion

This research showed that simple tools including development of the 'rich picture' and CATWOE analysis of SSM were useful in elucidating the real situation of the smallholder beef farming system. The hand-drawn rich picture encouraged farmers to comment and contribute to the discussion. Displaying the rich picture side by side with the table of the CATWOE analysis helped the participants to define their beef farming system as reflected in the root definition. To become operational, conceptual models which describe a set of logically-linked human activities required to improve the situation, should be developed based on the root definition (Checkland, 1999). However, in an asymmetric power situation, as in the case of smallholder farmers, it can be difficult to explore their opinions because of their low positional power (Hofstede, 2001); failure to recognize and accommodate this deficiency in research design thus might result in a less-than-comprehensive definition.

This is where 12Q CSH complements the CATWOE analysis of SSM. CSH enhances CATWOE in two aspects. Firstly, CSH enriches the criteria specified in the CATWOE. Six elements in the CATWOE were expanded into 12 elements in CSH as presented in Table 4. Secondly, CSH's ability to distinguish between *the actual is* and *the ideal ought to be* modes provides a construct for participants to make a comparison.

The *ought to be* mode of the 12Q CSH encouraged participants, including farmers, to speak and to give opinions about the ideal conditions for farming. Eliciting inputs about the ideal condition was easier because farmers considered it to be *risk-free*. It was more challenging interrogating the actual versus the ideal situation. The list of responses obtained from the previous farmers' interviews proved to be useful in initiating the debate. Using this list, even though comments were provided anonymously, made farmers aware that their opinions were also taken into consideration in the workshop.

Any gap between the real and the ideal situation indicates a potential problem which can be explored further. For the researcher, this was a practical tool, providing a reference point in interviews and a focus to encourage discussion. Without this tool, it would be difficult to define a problem because farmers commonly

Table 4: Stakeholder-generated CATWOE Analysis and responses to the 12 Questions of CSH

CATWOE(SSM)		12Q (CSH)			
Element	**Current situation**	**Element**	**Dimension**	**Ideal Condition**	**Actual Condition**
Customers	Farmers' household, cattle traders, government	Beneficiaries	Motivation	Beef farmers	Beef farmers (group member), cattle traders
Actors	Farmers	Expert	Knowledge	Farmers together with scientists, the local livestock service office and financial institutions	Group leader, peer farmers. (University and livestock office are always welcome to visit farmers, but farmers are mostly reluctant to come to their offices.)
		Expertise	Knowledge	Farming skills, marketing, network building	Feed preservation
		Guarantor	Knowledge	Knowledge and skills, objective, and politically impartial	Trust and social position
Transformation	Raise cattle to generate cash	Purpose	Motivation	To breed and raise cattle	Government: to increase beef population Farmers: to gain income
		Measure of Improvement	Motivation	Three indicators of improvement: number of cattle, income generated, group assets	Each pursued different improvement indicator; Government: cattle population; Farmers: sales revenue; Program coordinator: group assets
Worldview	To gain revenue for the household	Worldview	Legitimacy	To increase both cattle population and farmers' welfare	Farmers' worldview differed from those of government and program coordinator. Farmers view was improving their welfare; whereas Government and Program coordinator views were that the cattle population should be increased first, and then it would generate more income and improve farmer welfare.
Owners	Head of the group, farmers	Decision Makers	Control	Farmers	Group leader and program coordinator
Environment	Feed availability, price uncertainty, access to market, pricing policy	Resources	Control	Financial, high quality cows, feed, market access	Cattle bought mainly from grant, farmers provide feed, man power, and housing
		Decision Environments	Control	Fair pricing, fair market	Feed price volatility, dependency to local trader, imported live cattle, discouraging practice from politically-affiliated farmer group
		Witness	Legitimacy	Representative of the affected	Surrounding farmer, some group member feel as the affected of the program
		Emancipation	Legitimacy	Farmer groups offer a forum or media to discuss the affected perspectives	Routine monthly meeting, but mainly for members only

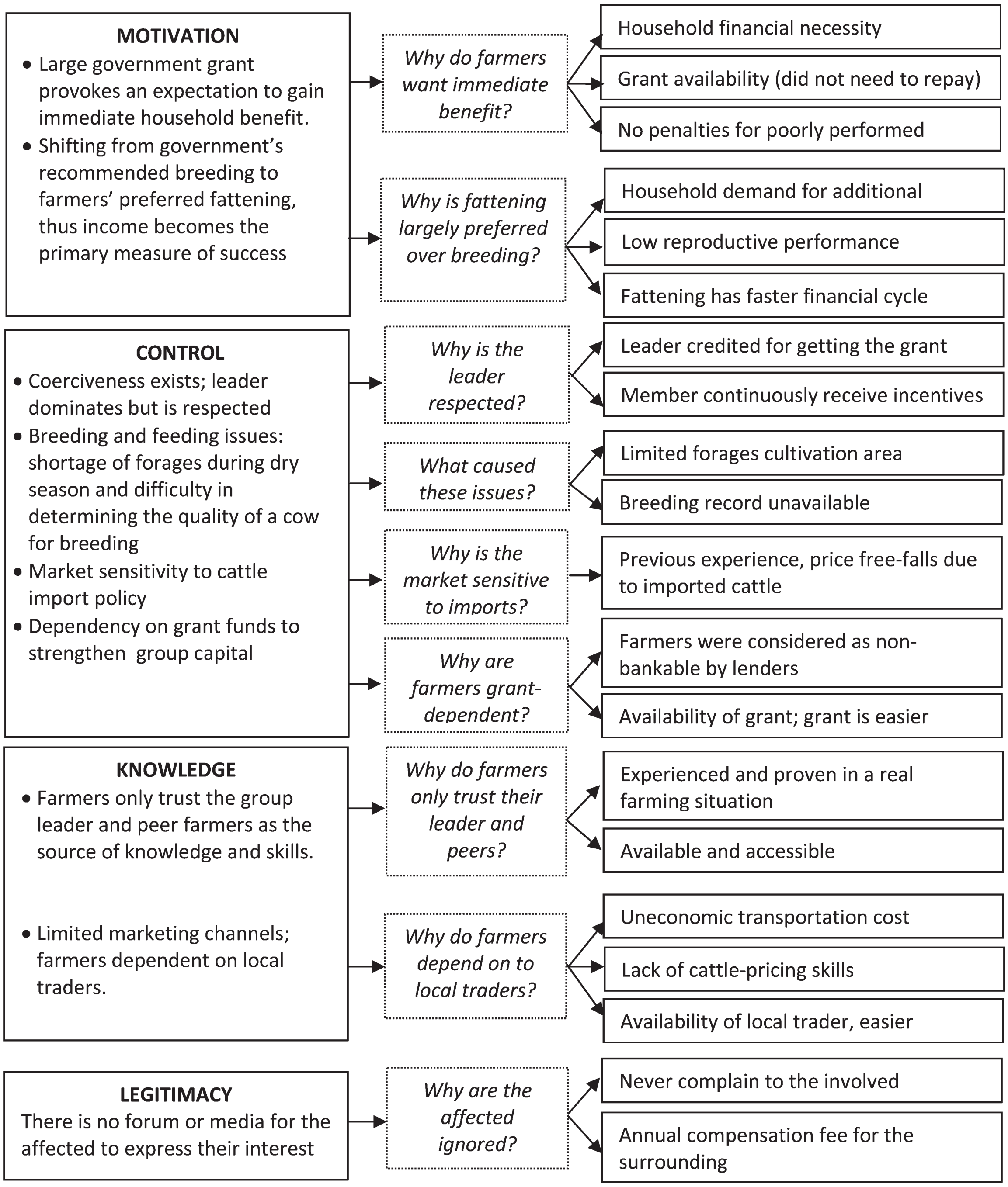

Figure 3: The problematic situation of smallholder beef farming in Central Java, developed from CATWOE analysis and the 12 questions of CSH

feel that the existing uncomfortable situation is "*normal*". This tendency is even more likely in a culture which has high power inequality as in Indonesia (Hofstede, 2001).

The fact that farmers and the government have different *purposes* and different *measures of improvement* indicates that with the 12Q CSH, farmers, although lacking positional power, were able to express their opinions. Purposes are closely related to motivations which will influence the level of engagement of the participants with the program (McAllister, 1999) whereas measure of improvement reflects *how participant measure the outcomes of the program*. Therefore a proper problem structuring method should elaborate purposes and outcomes in its framework (Midgley *et al.*, 2013)

Moreover, the four dimensions of the critiques (Figure 2) enabled the further exploration of the possible reasons behind the existing problematic situations. These reasons can be used as an input to design any possible and feasible intervention.

The combination of SSM and CSH facilitated the structuring of the problematic situations of the current smallholder beef farming system in a more sophisticated and holistic way than was provided by SSM alone. The combination of the methodologies was useful to identify and to structure the problematic situation of a system which has multiple stakeholders and positional power asymmetry issues in particular. Once the problems were properly identified and structured, they could be used as the basis to develop further intervention strategies.

However, the combination had consequences in that it increased the complexity of the methodology. Participants should be exposed into two sets of interviews and workshops. At some level, this might create an ethical issue of excessive calls on farmers' time. Thus, in this study the workshops schedule were adjusted with the regular farmers' meeting so that farmers did not have to allocate extra time specifically for workshops. Another possible problem that emerged was that some elements of the CATWOE and the actual *is* mode of the 12 questions of CSH were similar. Exposing participants to similar questions repeatedly might also bring ethical consequences. Participants might feel bored at the repetition, or that they had been initially ignored, on being asked the same questions repeatedly. Nevertheless, experience from the study showed that this is worth to risk, provided participants understood the need for the lines of questioning and were actively engaged in answering them.

During the CATWOE analysis, all participants agreed with the result of the analysis but when they were exposed to the 12Q of CSH and asked to critique the differences between the ideal *ought to be* and the actual *is* situations, some disagreements occurred. The disparity between the farming objectives of different participants revealed in this study indicates that the methodology was able to embrace the opinions of the less-powerful stakeholders - the farmers. The availability of the contrasting constructs of the *ideal* and *actual* conditions clearly provides a reference point for participants to explore and debate their opinions.

5. Conclusion

Our results show that in comparison to using SSM alone, the combination of SSM and CSH enabled better structuring of the problematic situation of a complex system which had multiple stakeholders and probable positional power asymmetry issues as in the case of smallholder beef farming. The collaboratively developed rich picture was able to assist both the participants and the researcher to express opinions and also learn more about the current farming situation. Further, the CATWOE analysis of SSM and the 12Q of CSH were useful aiding thorough investigation and better structuring of the problematic situations.

However, despite the advantages of enabling the structuring of the problematic situation in a four dimensional diagram, the combination of methodologies has the disadvantage of increasing the complexity of the investigation. It also has limitation in describing the causal relationship between the actors, the activity, and the problematic situation. Nonetheless, it provides an entry point for taming the complexity of the smallholder beef farming system in Central Java.

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REFEREED ARTICLE

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Economic comparison of pasture based dairy calf-to-beef production systems under temperate grassland conditions

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ABSTRACT

With the abolition of EU milk quotas in 2015, the Irish dairy sector is positioning itself for substantial expansion which will result in an increase in calves from the dairy herd available for beef production. A wide range of beef cattle production systems are possible for these extra calves reflecting differences in breed, gender and finishing age. The Grange Dairy Beef Systems Model was used to simulate beef production from male and female calves born to Holstein-Friesian dairy cows bred to late maturing, early maturing and Holstein-Friesian sires and finished at different ages. The most profitable system was finishing steers at 28 months of age with the least profitable system being finishing male animals as bulls at 16 months of age. All systems were sensitive to beef, calf and concentrate price variations. The main implications from this study are that, irrespective of the system, maximising the proportion of grazed grass in the diet and the percentage of live weight gain from grass while also maintaining a high carcass output per hectare are the main drivers of profitability. Other issues such as land and labour charges, bonus schemes and variations in beef, calf and concentrate prices are important and can differ considerably depending on farm circumstances. Therefore, these issues need to be considered when deciding between different dairy calf-to-beef systems.

KEYWORDS: Bulls; dairy beef; grass based; heifers; simulation; steers

1. Introduction

The abolition of the European Union milk quota system in 2015 (European Commission, 2009) is expected to lead to an expansion of the dairy cow herd in Ireland (DAF, 2010) which will lead to an increase in the number of dairy origin calves available for beef production. The majority of dairy cows in Ireland are Holstein-Friesian (AIM, 2012) and are bred to Holstein-Friesian (FR) sires to produce replacements, in addition to early maturing (EM; Aberdeen Angus or Hereford) and late maturing (LM; e.g. Belgian Blue or Charolais) beef sires to produce crossbred progeny that are finished within dairy calf-to-beef production systems. In the case of these dairy calf-to-beef production systems, the different breeds that are produced differ in many aspects including feed intake, kill out proportion, carcass conformation and fat class. Late maturing animals have a higher kill out proportion and conformation score than EM animals which are greater again than FR animals (Keane and Drennan, 2009). At the same slaughter weight, early maturing animals have a higher fat class than FR animals which in turn are higher than LM animals (Keane and Moloney, 2010). These factors influence the market for which each of the breed types are suitable and therefore, the suitability of different production systems differs depending on the breed of the animal (Keane and Drennan, 2008). The Irish beef industry is estimated to export approximately 90% of total production (DAF, 2013). The United Kingdom is the largest market for Irish beef accounting for 52% of exports (the main market for dairy origin animals); 47% of Irish beef exports go to other European countries and 1% to international markets (Bord Bia, 2012).

There have been few models that have studied beef production systems using calves from the dairy herd (e.g. Kilpatrick and Steen, 1999; Bonesmo and Randby, 2010; Ashfield *et al.*, 2012a,b and 2013a,b,c). Feeding strategies were modelled by Bonesmo and Randby (2010) who found that feeding bulls high energy grass silage during the finishing period increased profitability. Kilpatrick and Steen (1999) developed a model that predicted the growth and carcass composition of a number of cattle breeds over a range of different feeds. However, these studies were only concerned with the finishing stage of the system. Ashfield *et al.* (2012a,b and 2013a,b,c) studied dairy calf-to-beef systems at a whole farm level, however, differences in input and output prices made comparisons between systems across studies difficult. The studies of Ashfield *et al.* (2012a,b and 2013a,b,c) quantified the economic performance of

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subsets of the total finishing options that are available to dairy calf-to-beef farmers and therefore, did not permit a comprehensive across production systems comparison. Furthermore, the studies of Ashfield *et al.* (2012a,b and 2013a,b,c) did not take into account the effects of bonus schemes, land or labour charges which, although contingent on specific farm circumstances, can have a considerable impact on farm profitability. Thus, it is apparent that the majority of beef system models have focussed mainly on finishing systems and there is a paucity of whole farm models of dairy calf-to-beef production systems looking at the range of breeds, genders and finishing ages that can be achieved from the range of animals produced from the dairy herd.

Therefore, the objective of this study is to compare the profitability of a wide range of dairy calf-to-beef systems in the context of differences in breed, gender and finishing age at constant input and output prices to determine the most profitable systems, the main drivers of profitability for these systems and the effect of bonus schemes, land and labour charges on the profitability of these systems.

2. Materials and methods

Model description

The Grange Dairy Beef Systems Model (GDBSM) is a whole farm model and thus, it integrates the various components of beef farming systems into a single framework. The model adopts a single year static approach and assumes that the system operates in a steady state condition. This facilitates the technical and economic evaluation of dairy calf-to-beef production systems. The model is described in detail by Ashfield *et al.* (2013a) and so is only summarised here. It is an empirical model that uses data from production research experiments, conducted primarily at the Animal and Grassland Research and Innovation Centre, Teagasc, Grange, to specify coefficients and production functions (e.g. grazed grass dry matter digestibility and energy content, live weight gain and the monthly proportion of grazed grass and grass silage in the diet).

In setting up each model run, the farm land area owned and the cattle production system choices (e.g. animal breed, gender and age at slaughter) must be specified. Production systems modelled are based on three breed groups which represent the progeny of Holstein-Friesian dairy cows which are bred to LM, EM and FR sires. Within these three breed groups, male cattle can be produced as bulls or steers. Heifer finishing options are also included for EM and LM progeny but not for FR since it is assumed that all of these progeny are retained as replacements for the dairy production system from which they were bred. The model incorporates a range of finishing ages for each breed/gender combination. Animals within each group, according to breed, gender and finishing age, are assumed to be homogenous and consequently the model excludes variability among animals within groups. The forage system in terms of inorganic nitrogen (N) applied to the grazing area and number of grass silage harvests (one or two) must also be specified. Inorganic N application rates for grass silage production are set according to Teagasc recommendations (Coulter and Lalor, 2008).

The model consists of four sub-models comprising farm systems, animal nutrition, feed supply and financial components. A schematic diagram of how the different components of the model interact is shown in Figure 1. The default operation of the model does not include imputed charges for the opportunity cost of owned land and unpaid family labour (including the farmer's own labour). Key outputs from the financial sub-model are the monthly and annual cash flow and annual profit and loss account. All costs and margins are presented per farm, hectare, livestock unit (LU, an animal aged 0 to 12 months is 0.3 LU, 13 to 24 months is 0.7 LU and 25+ months is 1 LU), animal unit (AU, one AU equals an animal from purchase at 1 week of age to leaving the farm for slaughter) and kilogram of carcass sold.

Scenarios

In Ireland, there are a large number of different beef systems for dairy origin animals due to the different breed, gender and finishing age combinations that can occur. The selection of systems analysed in the current study were informed by the previous studies of Ashfield *et al.* (2012a,b and 2013a,b,c) and those systems most common in Ireland. Despite the lower profitability of finishing FR bulls at 16 months of age it was included in the current analysis because indications from the market are that bulls less than 16 months of age at slaughter are preferred (Dawn Meats, 2011). Therefore, to investigate the profitability of dairy calf-to-beef systems across a wide range of breed, gender and finishing age combinations a number of scenarios were investigated.

- Holstein-Friesian males finished as steers at 24 (HS24) and 28 (HS28) months of age, or as bulls at 16 (HB16) and 19 (HB19) months of age.
- Late maturing males finished as steers at 24 (LS24) and 28 (LS28) months of age and as bulls at 16 (LB16) months of age. Late maturing heifers finished at 21 (LH21) months of age.
- Early maturing males finished as steers at 20 (ES20), 22 (ES22) and 28 (ES28) months of age. Early maturing heifers finished at 19 (EH19) months of age.

All FR animals were born at the start of February and LM and EM animals were born at the start of March because in Ireland the number of calves born to a dairy (FR) sire and beef (LM and EM) sire peaks in February and March, respectively, (AIM, 2012). The calf rearing phase was as described by Ashfield *et al.* (2013a) finishing at the end of April. The first summer grazing period (when animals were outdoors consuming grazed grass only) was from the start of May to the end of October. Animals then commenced their first winter feeding period (animals were indoors and consumed a diet of grass silage and concentrate) after which production systems diverged. The animals finished at 16 months of age (HB16 and LB16) consumed a diet of *ad libitum* concentrate and grass silage and remained on this diet until they were finished at the end of May and June, respectively. Other animals destined for later finishing commenced their second summer grazing period in March and ended in October except for EH19 animals which were finished, off grass, in

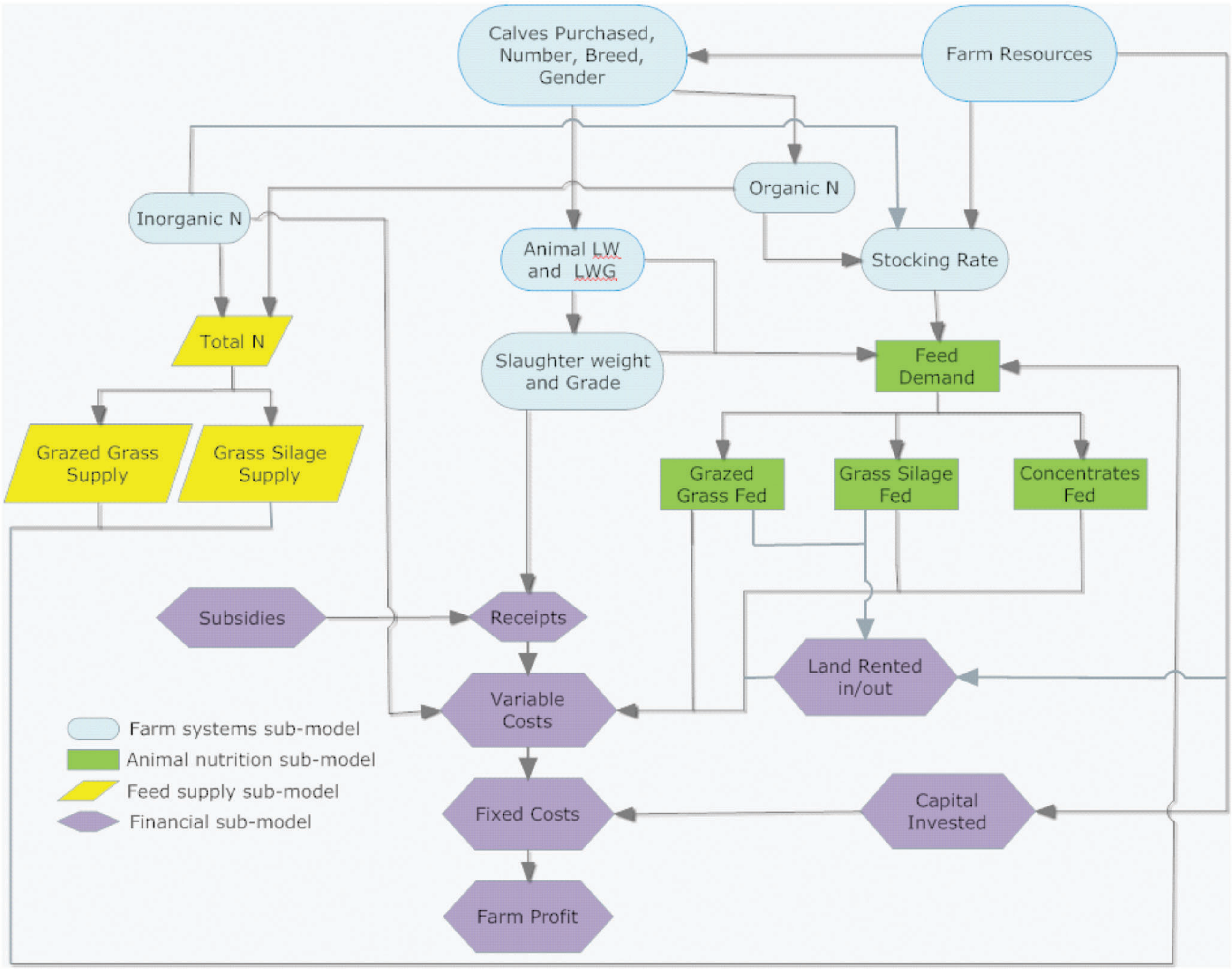

Figure 1: Schematic diagram of the Grange Dairy Beef Systems Model

September. In addition ES20 animals were finished off grass at the end of October. For EH19 and ES20, the finishing diet consisted of grazed grass and concentrates (receiving concentrate for the final 60 days). Older finished animals returned indoors for their second winter feeding period and consumed a diet of grass silage and concentrate. ES22, HS24 and LS24 were finished during their second winter feeding period at the end of December, January and February, respectively. Animals in the HS28, LS28 and ES28 systems returned outdoors for a third summer grazing period and were finished on a diet of grazed grass. HS28 animals were finished at the end of May with LS28 and ES28 animals finished at the end of June.

As the Nitrates Directive of the European Union (Directive 91/676/EEC) limits organic N output to 250 kg N ha^{-1} (DAF, 2008) stocking intensity was set below this limit (210 kg organic N ha^{-1}). This is the quantity of organic N excreted by animals on an annual basis with excretion rates of 65 kg for suckler cows and cattle greater than 24 months of age, 57 kg for cattle aged 13 to 24 months of age and 24 kg for cattle aged 0 to 12 months of age (DAF, 2008). Farm size was set at 50 hectares. Price and cost assumptions for all scenarios are shown in Table 1. All scenarios were subjected to sensitivity analysis with respect to beef, calf, concentrate and fertiliser prices. The live weight gains, slaughter weights, kill out proportions, carcass weights, conformation and fat class scores were taken from data produced at the Animal & Grassland Research and Innovation Centre, Teagasc, Grange and Johnstown Castle (Keane and Drennan, 2009; Keane *et al.*, 2009; Robert Prendiville, Teagasc; personal communication).

3. Results and discussion

Drivers of profitability

This paper compared a range of different dairy calf-to-beef production systems differing in breed, gender and finishing age. Table 2 presents the main physical results and Table 3 presents the main financial results for the systems investigated (unless otherwise stated the net profit does not include bonus scheme payments or a labour and land charge which are discussed separately later). The most profitable system was LS28 which had a very high proportion (70%) of grazed grass in the production system feed budget and the highest proportion of total life time live weight gain from grazed grass (81%). This finding is supported by Crosson *et al.* (2007) and Ashfield *et al.* (2013a) who found that the most profitable system had the highest proportion of grazed

Table 1: Prices used in the scenarios to determine the profitability of different dairy calf-to-beef systems[1]

Holstein-Friesian male calf price (€/ head)[1,2]	128
Late maturing male calf price (€/ head)[2]	355
Late maturing female calf price (€/head)[2]	335
Early maturing male calf price (€/ head)[2]	248
Early maturing female calf price (€/ head)[2]	248
Average annual beef price (R3 steer) (€/kg)[3]	434
Average annual beef price (R3 bull) (€/kg)[3]	427
Average annual beef price (R3 heifer) (€/kg)[3]	456
Calf concentrate (€/t)[4]	350
Yearling concentrate (€/t)[4]	300
Finisher concentrate (€/t)[4]	300
Milk replacer (€/t)[5]	2,100
Calcium ammonium nitrate (€/t)[6]	330
Urea (€/t)[6]	440
P & K compound fertiliser 0-10-20 (€/t)[6]	425
P & K compound fertiliser 0-7-30 (€/t)[6]	450

Notes: 1. At the time of writing (December 2013), €1=US$1.36, GBR£0.83
2. Irish Farmers Journal (IFJ) (2013a)
3. Bord Bia (2013a)
4. CSO (2013)
5. IFJ (2013b)
6. CSO (2012)

grass in the diet. Grazed grass is the cheapest feed available to Irish farmers (Finneran *et al*., 2012) and feed costs are one of the main drivers of profitability in beef production systems (Miller *et al*., 2001; Ramsey *et al*., 2005) and make up a large proportion of total variable costs (Ashfield *et al*., 2013a).

Therefore, those production systems with a higher proportion of grazed grass in the diet have lower costs of production. All systems studied take advantage of compensatory growth except the 16 month bull systems and compensatory growth has been shown to be advantageous by leading to increased live weight gain and reduced feed costs (Ashfield *et al*., 2013b). The 28 month systems have two winters of low live weight gain and therefore, can take advantage of compensatory growth, during the high nutritive value low cost summer grazing periods (Finneran *et al*., 2012), more than any of the other systems.

In general, the 28 month steer systems had the lowest live weight output per hectare but had the highest percentage of live weight gain from grass (Table 2). The three bull systems (HB16, HB19 and LB16) had the highest live weight and carcass output per hectare (Table 2) but also had the lowest net profit. Crosson *et al.* (2009) found that one of the main drivers of profitability in grass based beef production systems was carcass output per hectare. However, the bull systems in this current analysis had a higher level of concentrate intake relative to the steer and heifer systems (average kilograms of dry matter concentrate consumed per kg of carcass weight produced was 6, 2 and 1, respectively) resulting in higher feed costs and lower live weight gain from grass. Koknaroglu *et al.* (2005) and Ramsey *et al.* (2005) found that feeding higher levels of purchased feed led to higher costs and lower profits. Similarly, McRae (2003) found that it may be necessary to reduce carcass output per hectare to increase profitability per hectare where such a reduction in output is associated with an increase in the consumption of grass grown on the farm. Having a higher percentage of gain from grass also means that the cost per kilogram of gain will be lower and cost of gain was found by McDonald and Schroeder (2003) to be the second most important factor in determining the profitability of beef production systems. This, therefore, indicates that carcass output per hectare is a key driver of profitability of dairy calf-to-beef systems but it must not compromise the cost structure of the systems i.e. high carcass output per hectare must not be achieved by feeding an expensive feed source such as concentrate. In the systems studied this is achieved by maintaining a long grazing season (March to October) with high quality grass available at all times, thus ensuring that high live weight gains are maintained throughout the grazing season.

In Ireland, the number of bulls slaughtered as a percentage of total prime cattle slaughtered increased from 3 to 20% from 2000 to 2012 (Bord Bia, 2013b). This consists of animals from both the suckler and dairy cow herd and it is speculated that most of the increase in slaughtered bulls is from the suckler cow herd. The increase in bull beef production is due to bulls having a greater live weight gain, carcass gain, feed conversion ratio, conformation score and kill out proportion than steers (Seideman *et al*., 1982; Boucque *et al*., 1992; Steen, 1995; Steen and Kilpatrick, 1995; Keane, 2003; Kirkland *et al*., 2006). However, to express this greater animal production potential, bull beef cattle production systems are typically associated with higher levels of concentrate feeding. Therefore, as this study and Ashfield *et al.* (2013c) have shown, within the wide range of dairy calf-to-beef production systems investigated, bull systems have a lower net profit than steer systems. This is mainly caused by the high level of concentrate in the diet and, therefore, the increase in performance advantages (as described above) for bulls over steers is not sufficient to cover the increase in costs. This is exacerbated by the bull system's sensitivity to concentrate price which has increased by €50 per tonne between 2007 and 2012 (CSO, 2013).

Table 2: Physical outputs of dairy calf-to-beef production systems studied using the Grange Dairy Beef Systems Model

	HS24	HS28	HB16	HB19	LS24	LS28	LB16	LH21	ES20	ES22	ES28	EH19
Physical												
Number finished (animals)	127	100	241	181	127	100	241	155	167	145	100	181
Grazed grass consumed (kg DM/head)	2,698	3,898	565	1,130	2,612	3,953	661	2,152	2,276	2,655	4,017	2,016
Grass silage consumed (kg DM/head)	853	1,598	210	581	1,137	1,433	271	713	431	866	1,490	417
Concentrate consumed (kg DM/head)	841	513	1,760	1,567	724	292	1,611	488	461	329	433	210
Live weight output (kg/head)	604	685	523	596	652	720	561	545	518	573	713	450
Carcass output (kg/head)	312	343	276	315	351	395	308	287	269	297	363	230
Live weight output (kg/ha)	1,539	1,374	2,524	2,157	1,663	1,445	2,702	1,689	1,730	1,657	1,430	1,629
Carcass output (kg/ha)	794	687	1,333	1,139	895	793	1,486	890	896	858	729	832
Percentage total live weight gain from grass (%)	58	76	25	31	56	81	30	58	72	64	75	73
Labour requirement (MWU/farm)[1]	1.63	1.43	2.09	2.3	1.64	1.43	2.09	1.98	1.69	1.85	1.43	1.82

Notes: 1. MWU= Man work unit – one MWU is equal to 225 standard man days (SMD) – one SMD is equal to eight hours work by one person, SMD required per animal for calf rearing, animals outdoors and animals indoors are 1, 0.3 and 0.6, respectively, (Teagasc, 2008)

Sensitivity to price variations

Market volatility is an increasing challenge on Irish beef cattle farms with significant fluctuations in beef, fertiliser and concentrate prices in recent years (CSO, 2012). This means that the profitability of the different systems and the ranking of systems can change between years. Table 3 shows the effect of changing beef, calf, concentrate and fertiliser price on the net profit of the systems studied. Variation in beef price was found to have the largest effect on net profit especially the systems with higher beef carcass output per hectare. Fluctuations in calf price had a larger effect than concentrate price variations on all systems except the bull systems because of the high level of concentrate feed in the bull systems. Koknaroglu *et al.* (2005) found that more than 50% of the variation in profit is dictated by feed and cattle prices therefore, beef and concentrate price have an important influence on profitability. Fertiliser price changes had a small effect on all systems reflecting its lower contribution to total variable costs. The LS28 system was the most profitable and LB16 the least profitable for all variations in beef, calf, concentrate and fertiliser price. The ranking of Holstein-Friesian and late maturing systems changed within the beef price fluctuations shown in Figure 2. The fluctuation of calf, concentrate and fertiliser prices were also evaluated with calf and concentrate prices having a modest effect and fertiliser prices having no effect on the ranking of systems' profitability. The main effect of price changes was on the bull systems when beef and concentrate price is changed. Steer systems finishing cattle at grass at 28 months of age were found to be very robust to the range in prices investigated in this analysis.

Due to the large effect of changing beef price, the seasonality of beef price also has an effect on the profitability of the different systems. The seasonality of beef price is accounted for in the model with monthly variation captured based on historical data (Bord Bia, 2011). Ireland has a seasonal supply of animals to slaughter plants as a result of the numbers of beef cattle finished at grass at the end of the grazing season and the seasonality of calving with both the dairy and beef cow herds predominantly calving in spring. With the number of cattle slaughtered increasing in the autumn (August to November; AIM, 2012), animals sold in this period typically receive a lower price than animals sold in the January to July period. This is evident in the ES20 and EH19 systems which had the highest proportion of grazed grass in the diet 72% and 76%, respectively, high carcass output per hectare (896 and 832 kg ha^{-1}, respectively) and a high percentage of live weight gain from grass (72% and 73%, respectively).

However, the ES20 and EH19 systems were not the most profitable due mainly to the seasonality of beef price. However, this pattern of beef price fluctuation throughout the year does not always happen as was found in 2011 when beef price was higher for the second part of the year (Bord Bia, 2013a) due to seasonal price patterns being offset by a high demand and low supply of beef on the market. If the effect of seasonality on beef price is removed from the model it was found (Figure 3) that those systems finishing animals between August and December had an increase in net profit and those systems finishing animals between January and July had a reduction in net profit. LS28 is still the most profitable

Table 3: Financial outputs and effects of changing beef, calf, concentrate and fertiliser price on the net profit of dairy calf-to-beef production systems using the Grange Dairy Beef Systems Model (€000's per farm)

	HS24	HS28	HB16	HB19	LS24	LS28	LB16	LH21	ES20	ES22	ES28	EH19
Output												
Animal sales	163.8	145.3	280.1	229.1	194.7	176.2	325.3	184.9	177.4	174.7	159.0	169.6
Silage sales	0.0	0.0	6.1	3.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0
Livestock purchases	17.5	13.9	32.6	24.6	48.5	38.5	100.6	55.4	44.1	38.3	26.9	43.9
Total output	146.3	131.4	253.6	207.5	146.1	137.8	230.4	129.5	133.3	136.3	132.2	125.8
Variable costs												
Concentrate	41.2	20.4	158.0	105.8	35.4	12.0	143.7	29.7	30.3	19.3	17.2	16.2
Grazing grassland	6.8	10.0	3.5	3.7	6.6	10.1	4.2	6.3	8.3	9.1	10.6	7.5
Silage	8.1	12.4	3.0	7.6	10.9	11.1	3.9	8.2	5.5	9.5	11.6	5.7
Other[1]	28.5	24.1	48.2	38.0	30.5	25.2	52.1	33.6	33.4	30.8	24.5	34.7
Total	84.6	66.9	212.6	155.1	83.4	58.3	203.9	77.9	77.5	68.7	63.9	64.2
Gross margin	61.8	64.6	41.0	52.4	62.8	79.4	26.6	51.6	55.8	67.7	68.3	61.6
Fixed costs[2]	29.2	30.1	27.5	31.1	29.0	30.1	30.3	35.0	32.5	35.3	30.1	31.0
Net profit	32.6	34.5	13.4	21.3	33.7	49.3	−3.8	16.6	23.3	32.4	38.2	30.6
Return on capital invested (%)	2.35	2.78	1.18	1.87	2.19	3.45	−0.33	1.18	1.74	2.45	2.75	2.23
Sensitivity (impact on net profit farm^{-1})												
Beef price (+/−10c/kg)	4.0	3.5	7.2	5.7	4.6	4.1	8.0	4.3	4.3	4.2	3.8	4.1
Calf price (+/−€10/animal)	1.5	1.2	2.9	2.2	1.5	1.2	3.2	1.9	2.0	1.8	1.2	2.2
Concentrate price (+/−€10/t)	1.4	0.6	5.6	3.7	1.2	0.4	5.1	1.0	1.0	0.6	0.5	0.5
Fertiliser price (+/−€10/t)	0.2	0.3	0.1	0.1	0.2	0.3	0.1	0.2	0.3	0.3	0.4	0.2

Notes: 1. Veterinary and medicine, slurry, straw, milk replacer, reseeding etc
2. Includes machinery, land improvements and buildings maintenance and depreciation, other fixed costs and interest paid on overdraft and long term loan

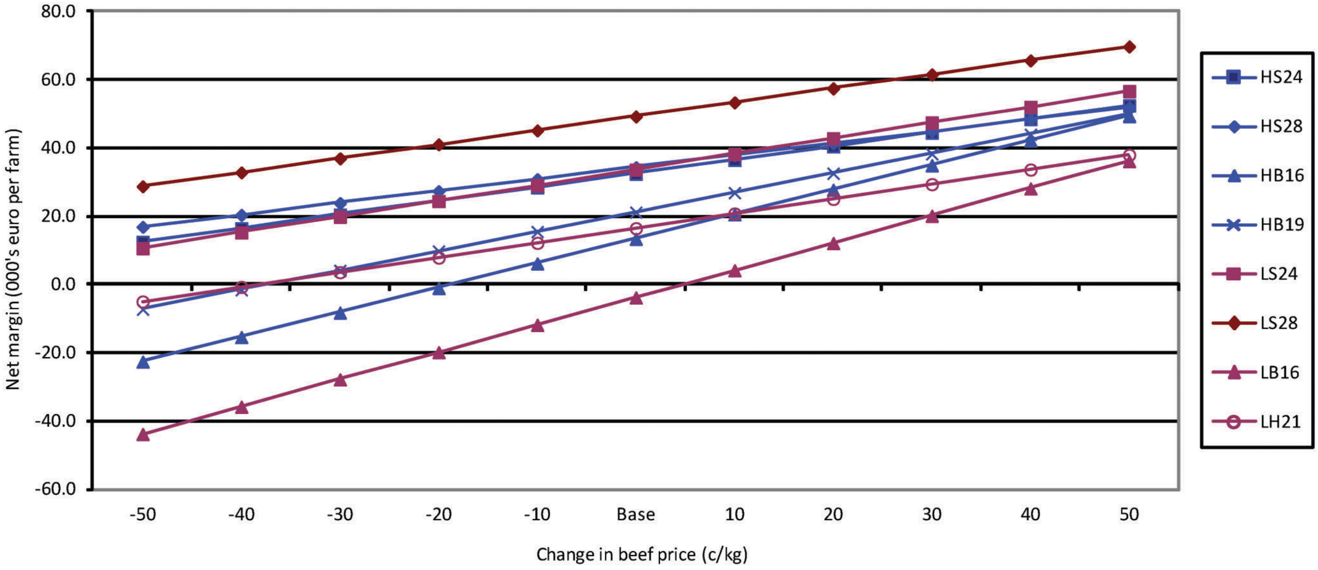

Figure 2: Effect of changing beef price on net profit of Holstein-Friesian and late maturing dairy calf-to-beef systems investigated using the Grange Dairy Beef Systems Model (all results in €000's per farm)

system and LB16 the least profitable system but the ranking of the other systems changes considerably (Table 4). This further emphasises the large effect changes in beef price can have on the profitability and ranking of the different systems.

Farmers face uncertainty about the economic consequences of their actions due to their limited ability to predict factors such as weather, prices and biological responses to different farming practices (Pannell *et al.*, 2000). Meuwissen *et al.* (2001) found that price was

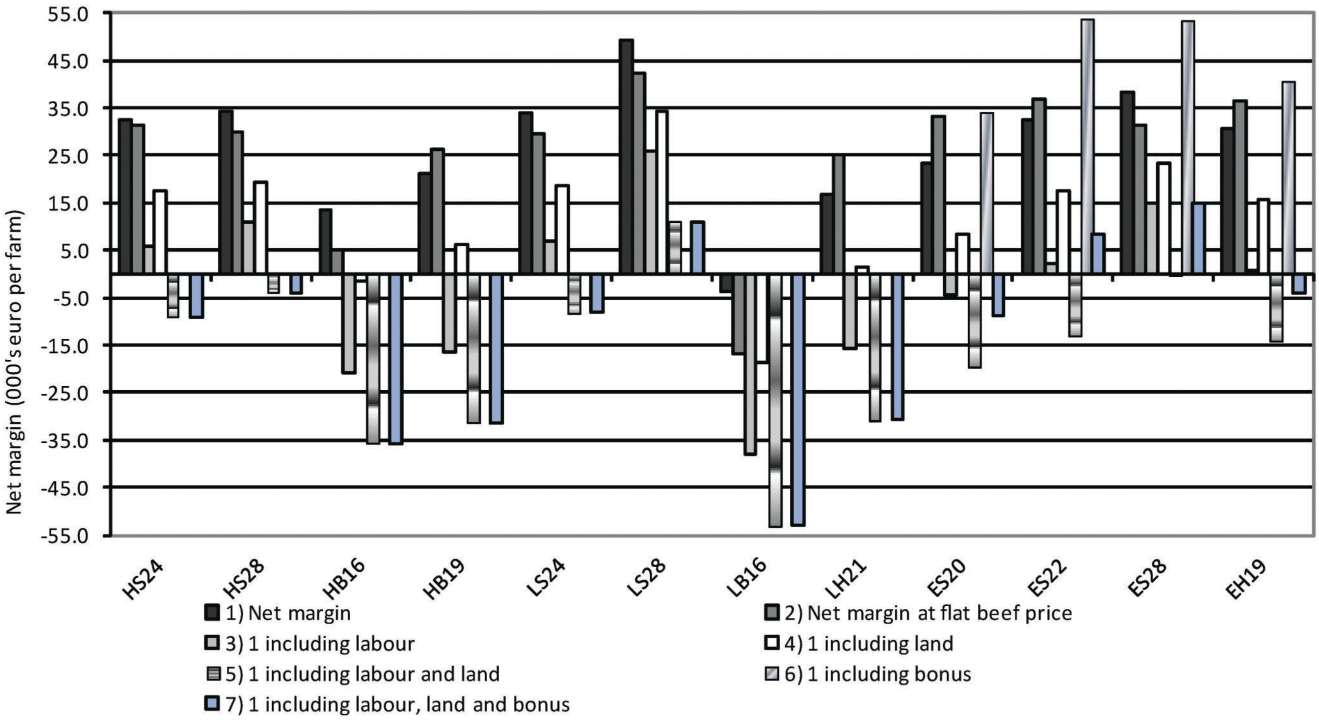

Figure 3: Profit measures for dairy calf-to-beef production systems investigated using the Grange Dairy Beef Systems Model (€000's per farm)

Notes:

1. Net profit excluding labour, land and bonus scheme paid for early maturing animals
2. Net profit with flat average beef price for the year
3. Net profit including labour
4. Net profit including land
5. Net profit including labour and land
6. Net profit including bonus scheme paid for early maturing animals
7. Net profit including labour, land and bonus scheme paid for early maturing animals

Table 4: Ranking of different dairy calf-to-beef systems to determine the effect of flat beef price, labour, land and bonus payments for early maturing animals

Rank	Ranking of systems (highest to lowest net profit per farm)											
	1	2	3	4	5	6	7	8	9	10	11	12
1) Net profit	LS28	ES28	HS28	LS24	HS24	ES22	EH19	ES20	HB19	LH21	HB16	LB16
2) Net profit at flat beef price	LS28	ES22	EH19	ES20	ES28	HS24	HS28	LS24	HB19	LH21	HB16	LB16
3) 1 including labour	LS28	ES28	HS28	LS24	HS24	ES22	EH19	ES20	LH21	HB19	HB16	LB16
4) 1 including land	LS28	ES28	HS28	LS24	HS24	ES22	EH19	ES20	HB19	LH21	HB16	LB16
5) 1 including labour and land	LS28	ES28	HS28	LS24	HS24	ES22	EH19	ES20	LH21	HB19	HB16	LB16
6) 1 including bonus	ES22	ES28	LS28	EH19	HS28	ES20	LS24	HS24	HB19	LH21	HB16	LB16
7) 1 including labour, land and bonus	ES28	LS28	ES22	EH19	HS28	LS24	ES20	HS24	LH21	HB19	HB16	LB16

perceived as one of the most important sources of risk. Therefore, this study has tried to encompass some of the risk involved around changing prices and it was found that there is considerably higher risk in the bull systems than the other systems. The bull systems were found to be more sensitive to beef, calf and concentrate price changes and have greater levels of money invested in livestock and variable costs for lower net profits than other systems which lead to higher levels of financial risk. This is further emphasised by the return on capital invested for the different systems shown in Table 3. The 28 month steer systems have the least risk in terms of price sensitivity and investment in livestock and variable costs.

An important aspect of risk refers to cash flow; in this regard the 24 month systems performed best with cash flow being negative for the shortest period of time (Figure 4). Figure 4 shows the monthly closing cash flow balance for the late maturing animals with all systems assumed to be starting from a zero balance position. The very negative closing balance for LB16 in May was due to large numbers of animals purchased in February and indoor feeding costs for calves and particularly finishing bulls prior to sale in June. Thus, high concentrate feeding also adds to the financial risk of the bull systems. The simulated overdraft requirement for the system would clearly represent a significant and unacceptable liability for many farmers and may have to take the form of a bridging/short term loan.

Bonus scheme, labour and land considerations

In Ireland there is a bonus scheme at slaughter for animals with an Aberdeen Angus or Hereford sire. This scheme gives farmers up to an extra 40c kg^{-1} of carcass sold for animals that meet the requirements (sire breed, carcass weight and time of year animals are finished). These particular requirements may be difficult to meet for many farmers, however, if this bonus is included in the current analysis the EM systems net profit increased by an average of €14,000 per farm (Figure 3). Therefore, this price increase would make the majority of EM systems more profitable than all other systems with the exception of LS28. Even where a bonus was available for EM systems, LS28 remains more profitable than ES20 and EH19 (Table 4), and HS28 would have a similar net profit to ES20. However, the bonus payable for EM systems is contingent on these breeds retaining a premium brand in the market and is thus a 'niche' market with the potential for oversupply. This could have significant negative implications on the bonus price received by the farmers (Tonts and Selwood, 2003).

The economic analysis presented thus far does not take into account the opportunity cost of labour and land. However, since the labour requirements are directly related to the number of animals in each system, the bull systems had considerably higher labour requirements than other systems (Table 2) requiring over two man work unit's (MWU; one MWU is equal to 225 standard man days (SMD) one SMD is equal to eight hours work by one person, Teagasc, 2008). The 28 month steer systems had the lowest MWU requirements. All systems required more than one MWU and this extra labour could consist of family members or hired labour, however, the availability of labour is

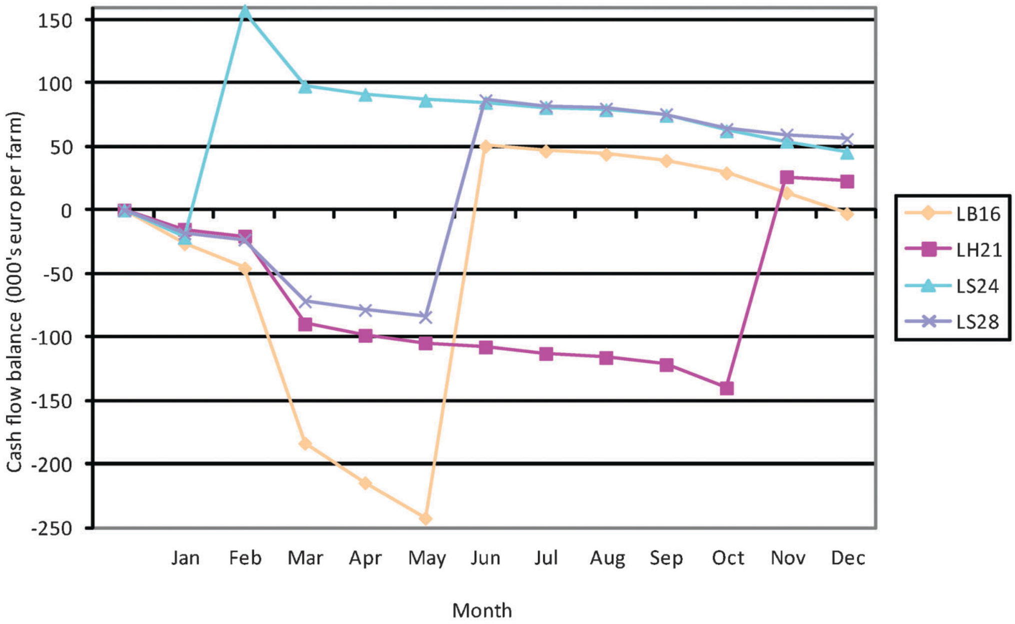

Figure 4: Cash flow of animals from late maturing dairy calf-to-beef systems investigated using the Grange Dairy Beef Systems Model (all results in €000's per farm)
Note: Opening bank balance (1st January) was assumed to be zero for all systems

decreasing on Irish farms (Frawley and Phelan, 2002). Labour requirements are seasonal with peaks in labour requirement around times such as calf rearing. There have been a number of studies into the reduction of labour requirements on Irish farms (Gleeson *et al*., 2008; O'Brien *et al*, 2006). Gleeson *et al.* (2008) found that labour requirements during calf rearing could be reduced by adopting new practices such as feeding once a day. This practice could be very important for the systems with high labour requirements such as the bull systems and could result in a reduction of total labour requirements for the systems. The net profit including the cost of labour for all systems is shown in Figure 3. For all systems labour costs averaged €29,000 (based on labour requirement taken from Table 2 and labour charge of €9.10 per hour (Irish Farmers Association (IFA), 2011)). This resulted in all bull systems, LH21 and ES20 having a negative net profit when a charge for labour was included.

Most farms in Ireland are predominantly family farm units with on average 83% of land owned (Hennessy *et al*., 2013). However, if a land charge of €300 ha^{-1} (Finneran *et al*., 2010) is applied to all land farmed including owned land, €15,000 is added to the cost of all systems (Figure 3). When labour and land charges are included (Figure 3) the only system to have a positive net profit is LS28. This shows the importance of considering labour and land charges when evaluating the profitability of the different systems and farmers need to ensure sufficient returns to cover these. When labour, land and bonus payments are all included the only systems to have a positive net profit are ES28, LS28 and ES22 (Figure 3).

4) Looking to the future

In 2011 there were approximately 1.1 million dairy cows in Ireland (AIM, 2012). The majority (63%) of these dairy cows were mated to a FR sire, 9% to a Limousin, Charolais or Belgian Blue sire and 22% to a Aberdeen Angus or Hereford sire with the remaining dairy cows mated to other breeds. The number of male animals from the dairy herd available for beef production in 2011 was 347,000, 121,000 and 22,000 for FR, EM and LM animals, respectively. Heifer numbers are more difficult to calculate due to the retention of a proportion of the EM and LM heifers as replacements for the suckler beef cow herd. Thus, it is clear that despite the LS28 system being the most profitable, the availability of LM calves from the dairy herd will limit the potential to exploit this finding. However, irrespective of the breed of animal the current study has shown that the most profitable system across all breeds is finishing animals at 28 months of age and this finding is supported by Ashfield *et al.* (2013a,b). The high ratio of FR animals to LM and EM animals could change in the future due to an increase in the number of dairy cows in Ireland after the abolition of milk quota in 2015 (European Commission, 2009) and the uptake of sexed semen due to the advantages outlined by Hutchinson *et al.* (2013). This could result in a larger number of beef breed (LM and EM) animals and lower number of FR animals being available for beef production. Furthermore, this could also lead to an increase in the number of heifer calves because natural service (i.e. cows served by a breeding bull) is likely to be the source of LM and EM sires resulting in a more even split in gender ratio. The selection of beef sires for use on dairy cows is driven by the requirements of the dairy farmer and thus shorter gestation length and lower incidence of calving difficulty will be most important. This would favour the use of EM rather than LM sires (Keane, 2002; ICBF, 2006).

In Ireland the majority of dairy cows calve in the spring (February-April; AIM, 2012). The majority of FR animals are born earlier followed by LM and EM animals due to Holstein-Friesian sires being used at the start of the breeding season to breed replacement heifers for the dairy herd. There is a range in calf birth dates with the majority of animals born from January to April which could affect the net profit of the different systems. In the current study the calf birth date is set as February for FR calves and March for LM and EM calves. Unpublished work based on ongoing breed and system comparison experiments at the Animal and Grassland Research and Innovation Centre, Teagasc, Johnston Castle looking at EM animals born in February or April would suggest that the animals born in April are more profitable (Prendiville *et al.*, 2013), however, more work is required to determine the underlying profit drivers leading to these differences.

The 16 month bull beef systems are unlikely to be managed as individual systems due to the challenges with regard to grassland management as only calves consume grazed grass for a short grazing season (May-October). The bull systems all required excess grass from the grazing area to be harvested as round bale grass silage and sold off farm. This system is more likely to be run in parallel with another production system to facilitate better synchrony of total farm grazed grass demand and grass growth. McRae (2003) states that it may be necessary to run different ages and classes of livestock on the same farm, to ensure higher profits per hectare through the better utilisation of grass. In Ireland dairy calf-to-beef production systems are seldom run as stand-alone systems and usually in conjunction with another enterprise (suckler beef cows, dairy cows, sheep). Results from Ashfield *et al.* (2013c) found that there was no advantage to the combining of different dairy calf-to-beef systems; however, this was in the context of rigid production systems with set feeding systems, fixed dates for turnout to grazing and housing for indoor feeding. It is possible that a more flexible approach to combining production systems taking into account the specific requirements of different systems and the variability of grass growth might permit higher profit tailored combination systems to be developed. A further area of possible future research could be looking at combining suckler beef cow or dairy cow systems through combining the GDBSM with the Grange Beef Systems Model (Crosson, 2008) or the Moorepark Dairy Systems Model (Shalloo *et al.*, 2004), respectively, to determine if combining these systems could lead to an increased net profit for the farm. In the current study it was not possible to analyse LM 19 month bull systems or 16 and 19 month EM bull systems because there is no research data available for these systems and therefore, this is an area where future research could be conducted. Although in this current study we have calculated a labour requirement figure for the systems based on data from Teagasc (2008) this uses a very basic method based on the age of the animal. Therefore, further research should be conducted in the area of labour requirements on dairy calf-to-beef farms to more accurately account for the labour required and associated costs for the different systems. All the systems analysed in the current study are assumed to have a very high level of management by the farmer. Clearly the level of management and animal husbandry has a critical impact on overall farm system productivity and consequently profitability. Therefore, another area of future research could be modelling the effects of poorer management such as reduced live weight gain or grass utilisation on net profit. The results from the current study would imply that future research prioritisation should be focused on maximising the proportion of grazed grass in the diet and the percentage of live weight gain from grazed grass while maintaining a high carcass output per hectare (through the production and utilisation of more grazed grass) as these are three of the main drivers of profitability in dairy calf-to-beef systems.

5) Conclusion

The GDBSM was used to compare the profitability of a number of dairy calf-to-beef production systems differing in breed, gender and finishing age. The most profitable system was found to be finishing late maturing animals at 28 months of age during their third summer grazing period (LS28). Variations in beef and concentrate price were found to have a significant effect on the ranking of systems. The main drivers of profitability were found to be maximising the proportion of grazed grass in the diet and percentage of live weight gain from grass while also maintaining a high carcass output per hectare.

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BOOK REVIEW

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Communication for Innovation: Rethinking Agricultural Extension

Cees Leeuwis (with contributions by Anne van den Ban)

Third Edition, published by Wiley-Blackwell, Oxford, UK. Paperback published 2004: ISBN 978-0-632-05249-3. 428 pages. Price £50/€60. E-book published April 2013: ISBN: 978-1-118-68801-4. 424 pages. £40.99/ €48.99.

Context

When Daniel Lerner published his influential book *The Passing of Traditional Society* in 1958, the potential role of communication in promoting development was glorified. This idea that communication can transform societies quickly became the dominant paradigm. Prominent figures of the modernization theories like Daniel Lerner (1958), Wilbur Schramm (1964), and Everett Rogers (1962), presented communication as a crucial factor in the development process.

Lerner's communication theory of modernization relied not only on the *hypodermic needle effects* theory of mass media or the *stimulus-response* theory of mass media effects, but also drew on the Freudian theory of irrational human behavior, the concept of mass society, the mathematical theory of communication (Weaver and Shannon 1949), and Harold Lasswell's (1958) conceptualization of communication process (Melkote and Steeves, 2001).

Based on sociological research in agrarian societies, Rogers identified five categories of adopters: innovators, early adopters, early majority, late majority, and laggards. He also observed that the adoption of innovation occurs through five stages (initially described as awareness, interest, evaluation, trial and adoption, but later as knowledge, persuasion, decision, implementation, confirmation); with mass media playing a crucial role in the first two stages and interpersonal communication channels being more effective in the last three (Rogers, 1995, Rogers, 1962).

Just as the "*leap forward*" expected from the implementation of modernization theory never materialized, participatory communication process–the new dominant paradigm–has its limits. Notably, there are questions and a variety of opinions, not only about the meaning, principles, practice, evaluation, benefits, and impact of participation, but also allusions that the concept of participation might be somewhat utopian. Nevertheless, participation is now widely (if not universally) recognized as a critical factor of sustainable development. Yet, there is room for improvement (Ukaga and Maser 2004, Moumouni and Ukaga 2006).

It is against this backdrop that I see this book, *Communication for Rural Innovation*, providing new and useful insights about agricultural extension in particular and development communication in general. Designed as an update to its predecessors, *Agricultural Extension* by Van de Ban and H. S. Hawkins (1988, 1996), this book offers fresh thinking about communication for innovation and its application to agricultural extension.

Content

The book consists of 20 chapters grouped into six parts. Part one consists of chapters: (1) introduction, (2) from extension to communication for innovation, (3) the ethics and politics of communication for innovation, and (4) the role of communicative intervention in policy planning. Discussed in this part are challenges facing agriculture and their implication for extension, conceptual evolution from agricultural extension to communication for innovations, political and ethical dimensions of communication for innovations, and (instrumental versus interactive) approaches to communication for innovations.

Part two consists of chapters: (5) understanding human practice, (6) knowledge and perception, and (7) communication and the construction of meaning. Discussed in this part are the role of knowledge and perception in human practice, communication and innovation, as well as key concepts in the field of communication and innovation studies.

Part three consists of chapters: (8) changing perspectives on innovation, (9) social and individual learning, (10) negotiation within interactive process, and (11) the role of outsiders and different intervention approaches. Based on the premise that more than mere distribution of information is needed to achieve desired change, organization of innovation process is discussed as a way to assure that communication is used primarily to facilitate network building, social learning, and negotiation. Part three ends with discussion about striking the right balance between instrumental and interactive communicative intervention.

Part four consists of chapters: (12) the potential of basic communication forms and media, (13) communication for innovation methods, (14) the management of interactive innovation process, and (15) the planning of individual activities. Discussed in this part are potentials inherent in basic communication media and forms, specific communication methods, interactive process, and the planning of individual activities.

Part five consists of chapters: (16) organizational management, learning and research, (17) agricultural knowledge and information systems, (18) privatization and the emergence of knowledge markets, and (19) the cooperation across scientific disciplines and epistemic communities. Based on the premise that an enabling environment allows professionals to contribute more effectively to change and innovation, this part discussed different ways of looking at organizations and their management. Inter-organizational issues, knowledge markets, and cross-disciplinary cooperation are also discussed as topical issues that relate to the organization of communicative intervention.

Part six, the epilogue, consists of chapter 20. This final chapter suggests additional conceptual research needed to better understand the relationship between communication and innovation.

My Thoughts

The book is based, among other things, on two premises: (1) change and innovation are uncontrollable/unpredictable multi-actor processes, and (2) communication efforts aimed at facilitating both change and innovation would benefit from theories of social learning and negotiation. Fundamentally, it calls for adaptation of what extension is and why it is important. It also contains other nuggets of wisdom including the following.

Societal problems usually result from the way people interact with each other and with their natural environment. Hence, sustainable solution to these problems should involve development of new kinds of relationships with each other and the environment. This in turn requires shared modes of thinking and agreements among stakeholders, which calls for management of interactive processes - such as network building, learning, and negotiations–to bring about the desired relationships. Notably, an interactive approach to communication is based on different ideas and assumptions–such as the unpredictability of change–from the instrumental model. Nevertheless, "a certain balance and interaction between instrumental and interactive intervention activities may be required in several instances."

Communication can be a powerful instrument for change because it is an important process through which experiences are exchanged, knowledge acquired/shared, and perceptions molded. However, communication workers such as extension agents are not the only ones with relevant expertise. Target audiences generally have unique knowledge and expertise about their specific situation. "The challenge for communication workers, then, is to offer a different kind of 'expertise' that recognizes" and enhances local knowledge and experiential learning. "In doing so, however, it will be unhelpful to develop one rigid package of innovations, as this tends to undermine the capacity to deal with diversity."

Beyond appreciation of local expertise and diversity, there are other critical factors such as media selection and organizational climate. Notably, "media choices can have 'political' implications in the sense that they are to the benefit of some and to the advantage of others." Therefore, it "is important for communication workers to reflect on the significance of unequal media access in a particular context and to take action to avoid negative consequences." Further, communication workers and their organizations need to be adaptive and responsive to continued change in order to effectively meet challenges facing extension. This requires an organizational climate in which people are free to act according to their best professional judgment and not expected to always do only what they are told from above.

This book expands and updates the knowledge base about agricultural extension and communication for innovation. Content is logical, theoretically supported, and highly cross-referenced. It includes theoretical and practical implications that can help communication practitioners, researchers, and policy makers improve their effectiveness.

Okechukwu Ukaga[1]

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VIEWPOINT

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Rural businesses: central to the countryside or just an add-on?

ROGER TURNER[1]

ABSTRACT

A Consultant in Rural Economies and Honorary Fellow at Newcastle University's Centre for Rural Economy asks whether, after months of debate concerning funds for future economic growth and rural development, UK professionals have represented rural economies well.

KEYWORDS: rural development; European policy; advocacy; equity; economic growth

Where does the future of our countryside lie? Understandably, some will argue that good land management must remain at the heart of rural economies and society, and requires ongoing, adequate, direct payments to farmers and land managers. Nobody would dispute that growing food is important. Few would argue against long- term environmental stewardship. At the same time, others validly call on governments to match funds to today's profile of rural economies, drawing on a myriad of evidence that many rural areas have long ceased to be dominated by land-dependent enterprise and communities, and their needs and outputs. Both perspectives may be correct, determined as much by where you operate, advise or represent, as by the evidence on which you draw to justify your point of view.

Whichever perspective reflects your experience, we should avoid this debate amongst rural friends distracting us from the more important goal of gaining equitable recognition for rural areas from those now tasked with distributing future resources. A shift in rural funding towards rural growth from non-farm and -food industries could rescue hundreds of thousands of rural enterprises and employees from such marginalising and devaluing phrases too often heard in speeches by our rural leaders, including UK government ministers, as 'farming, food *and other rural businesses*' (my emphasis)

Moreover, a significant shift of rural funds to growth and landscape- scale environmental management schemes for example, would send a powerful signal to those who hold, target and distribute funds not labelled 'agriculture' or 'rural'. Rural economies and societies are more than the land, are not marginal, not homogenous, and not without potential. They share diversity and opportunity with urban economies. They deliver outputs and benefits, similar to and occasionally exceeding those of our towns and cities. Yet they retain special and additional environmental and community qualities which society and governments need to steward. Rural sustainable and inclusive growth is as much the responsibility of business and public bodies as growth from our towns, cities and global linkages.

Since last Autumn, a new approach of integration and devolution arising from the EU's Common Strategic Framework, has generated rare opportunities for communities across urban, rural, coastal, remote and densely-populated areas to help set priorities, develop programmes and projects, and target funds for the next 6 years. In England alone the nationally co-funded EU structural and investment funds are worth around £9.1 billion[2], and rural needs deserve to be accurately and visibly embedded within these commitments. The insight and voice of rural professionals is sorely needed.

Local Enterprise Partnerships (LEPs) provided the first of these opportunities, when they consulted on their draft European Structural and Investment Funds (ESIF) Strategies. Defra[3] ministers and counterparts in Scotland, Wales and Northern Ireland launched the second opportunity as they consulted on reformed Common Agricultural Policy (CAP) budgets and payment regimes. Both have far reaching impacts on the balance of growth between different types of territory, and between beneficiaries and projects within rural and other places. The CAP Reform discussion was the most comprehensive and open consultation about national allocation of EU's rural funds that I can remember, since the UK Government's ALURE (Alternative Land Uses and Rural Economy) initiative in the mid-1980s.

Responding to a plethora of advice from the UK Government last summer, LEPs' Growth and Economic Strategies set priorities for distributing EU funds between 2014-20. Final versions currently await Government sign-off. Some LEPs mirrored the spirit of integration from the EU Framework, setting priorities and proposals such that any group, community or business, working to deliver its strategic objectives should be eligible to bid for funds, irrespective of their location, Regrettably this seamless approach is far from universal.

Industries, functions and economic drivers adopted as the focus of some LEP Strategies, will marginalise or

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[2] At the end of May 2014, £1 was approximately equivalent to $1.67 and €1.23 (www.xe.com).

[3] The United Kingdom Government Department for Environment, Food and Rural Affairs.

exclude some territories and communities, including rural ones, by their design. There was minimal focus on the Protection of environment, Climate change and Transport objectives, whilst Rural Development priorities were absent or weakly addressed until Defra allocated targeted rural funds, i.e. the European Agricultural Fund for Rural Development (EAFRD).

Other LEPs perpetuate weak practices and outdated perspectives of rural economies, profiling only their farming, food or tourism activities, or committing to invest in rural and environmental activities *only if* EAFRD funds are provided to them. The perception of rural weakness, set out in the SWOT analysis of one substantially rural LEP, illustrates a much wider challenge: ''Lack of coherent vision and voice for environment and rural sector and missed opportunities to innovate and contribute to wider economic development'' [*sic*].

Unless rural Departments and stakeholders overturn such outmoded perceptions in economic partnerships and agencies, rural economies and communities will remain semi-detached from this integrating and rebalancing aspiration.

In November 2013, Defra's Secretary of State laid out an opportunity and challenge to farmers, business and community leaders across rural regions no less substantial and critical to our rural futures. The balance between direct payments to farmers, and funds for growth and development in the wider, and often more substantial, non-land rural enterprises, lay at the heart of this discussion

Although we had glimpsed tense and prolonged EU negotiations over CAP in 2013, with hints of substantial shifts of resources to rural development, I suspect that few of us expected to be offered a comprehensive and open opportunity to have our say on future directions for Britain's countryside. The questions and supporting evidence, ranged across Principles to inform a strategic shift of up to 15% of Pillar 1 (Direct Payments) into Pillar 2 budgets, to detailed choices for investment, growth, environmental enhancement and climate adaptation in rural economies and places.

Similar exercises were undertaken by Scottish, Welsh and Northern Irish Governments and Assemblies. The options and balances offered by each country rightly reflected the different characteristics and contributions made by traditional industries to the UK's rural and country economies. Thus, we have a range of frameworks across rural UK, enabling countries' rebalanced budgets to re-allocate between 9.5% and (eventually) the full 15% to Pillar 2. We can also look forward to new Small Rural Business grants, new LEADER funds, and new Farm and Forestry Competitiveness funds–but their individual scale are dwarfed by other EU/UK Structural and Investment Funds and direct payments to land managers

As rural professionals our insight and expertise to bring together and balance competing demands and outcomes, is needed to ensure that 'rural' is an integral part of rebalanced economies at local, national and EU levels. I hope we all grasp the opportunities offered by these debates and plans.

Acknowledgement

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Farmer characteristics associated with improved and high farm business performance

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ABSTRACT
Common Agricultural Policy reform, coupled with increasing market and climatic volatility will necessitate a competitive, resilient and environmentally sustainable UK agricultural industry reliant upon successful farm business management. Drawing upon in-depth semi-structured interviews with 24 'high' or 'improved' English farmers, results indicate that they typically hold agricultural qualifications, draw upon a range of information sources, recognise and draw upon farm-specific advantages, have low business debt, keep up to date with new industry developments and use a range of marketing channels. Additionally, these farmers seek to maximise profit within the context of farm and family objectives by focusing upon cost control, attention to detail, product quality and achieving high yields whilst primarily focusing upon enterprise margins; succession planning played an important role in decision making on some farms. Farmer decision making represents the outcome of responses to complex inter-linked issues; policy makers face the challenge of understanding this complexity and delivering policies that will generate multi-output objectives.

KEYWORDS: Business Performance; Farm Business; Objectives; Managerial Characteristics

1. Introduction

Background

European agriculture faces numerous challenges. Reduced Common Agricultural Policy (CAP) support (ABC, 2012), increasingly volatile input and output prices (Heyder *et al.*, 2010) and extreme variations in weather patterns (Beniston *et al.*, 2007), combined with a demand for agriculture to contribute to climate change mitigation (Smith *et al.*, 2000), provide ecosystem services (Ma *et al.*, 2012) and food security (Godfray *et al.*, 2010), necessitate a competitive, resilient and environmentally sustainable agricultural industry. The large variation in farm physical and business performance flows from variation in farm systems, geographical situation and managerial actions and characteristics (Langton, 2011). Beyond changing farm system, adopting different managerial practices can enhance technical efficiency (Wilson *et al.*, 1998; 2001) and business performance (Defra, 2010) and potentially result in 'win-win' - 'profit-environment' scenarios which are of particular interest to policy makers (Foley *et al.*, 2005). Lower productivity growth in UK agriculture relative to EU competitors (Thirtle *et al.*, 2004) demonstrates the need for UK policy makers to understand drivers of agricultural performance within sustainable food production systems. However, the concept of 'performance', and the key drivers influencing performance, is subject to considerable debate within the literature, encompassing aspects of financial return, ecosystem services delivery, societal benefits and diversification activities.

Metrics of Agricultural Performance and Financial Return

'Agricultural performance' has typically been assessed via efficiency, profitability and financial investment return metrics. Efficiency studies within a UK context include Dawson (1985), Wilson *et al.* (1998; 2001), Hadley (2006), Barnes (2008) and Barnes *et al.* (2009). These studies have frequently highlighted the variation in efficiency; explanations for this variation include managerial biographical factors (Wilson *et al.*, 1998), and managerial objectives, actions and behaviours (Wilson *et al.*, 2001; Wilson, 2011). Hadley (2006) and Barnes *et al.* (2011) identified that more efficient farms had lower debt ratios. Moreover, low levels of debt have also been associated with higher performance (Langton, 2011; 2012). Business performance metrics include accounting financial approaches (profit [e.g. £/farm]), economic return (net margins [e.g. £/farm, valuing all land on a rental basis and valuing unpaid labour]) and return on investments (return on assets (RoA) / return on equity (RoE) [e.g. £/£ of assets or equity]); hence understanding the basis of the metric chosen is of importance in business performance analysis. Langemeier (2011) utilised profit and growth metrics

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to categorise crop/beef farms in Kansas into four groups based upon their relative profit and growth metric ranking combinations. The Du Pont model (see Barnard and Boehlje, 2004) provides an approach which combines a range of profitability and business return metrics and has been demonstrated to provide key advantages over area based profit metrics (Shadbolt, 2012), facilitating comparability across farms irrespective of size (Gloy *et al*., 2002). Blank's (2005) analysis indicates that while a number of American farms and ranches have low profit, they accrue RoA and RoE rates of over 4%. Shadbolt's (2012) analysis demonstrates no difference in RoE and RoA between New Zealand dairy systems, albeit that significant differences exist across production or profit metrics per hectare by system type, indicating that per hectare metrics in this context were a less valid performance measure. Gloy *et al*. (2002) used RoA as the measure of performance in analysing New York Dairy farms, while Zhengfei and Lansink (2006) chose RoE as the financial performance metric for analysis of Dutch arable farms. However, the relevance and choice of the appropriate performance metrics fundamentally depends on the context of enquiry (Barnard and Boehlje, 2004). A primary interest in return to input use would indicate the need for economic accounting; policy interest in shorter term viability of agricultural incomes make profit metrics appropriate; strategic analysis would lend itself to investment return metrics.

Farmer Attitudes and Behaviours

Defra (2011a) recommended that financial performance should be examined in conjunction with information on managerial objectives in order to provide holistic analyses of performance. Barnes *et al*. (2011) note the importance of farm attitudes, business actions and collaborative networks as drivers of performance. May *et al.* (2011) argue that the intensity with which farmers engage and interact with networking activities is of greatest importance in developing innovative capacity. Farmer segmentation analysis (see the seminal work of Gasson, 1973) explores the rationale and reasons behind managerial choices, placing farmers into particular behavioural groups (Garforth and Rehman, 2006; Dwyer *et al*. 2007; Defra, 2008; 2011b) with recent work analysing farm performance in association with segmentation groupings (Wilson *et al*., 2013). While financial return remains of importance to farmers (Robinson, 1991), segmentation analyses have identified that environmental, land and business stewardship play important roles in farmer decision making. Others have classified farms along a productivist to multifunctional spectrum (Wilson, 2008) albeit that Marsden and Sonnino (2008) argue that multifunctional activity should include financial business benefits. Langton (2012) concludes that demanding environmental schemes adversely affect agricultural efficiency, though can lead to positive impacts on the whole farm business. Differences in non-production practices can be linked to motivational differences (Schoon and Grotehhuis, 2000), but also policy and market drivers (Hodge, 2001; Morris and Winter, 1999). Siebert *et al.* (2006) note that while financial payments are often a necessary condition to engage farmers in the delivery of biodiversity goods, 'farmer attitudes', experience and social attitudes are also important. Burton (2004) additionally highlights the importance of understanding the farmer's identity. Burton *et al.* (2008) and Burton and Paragahawewa (2011) have argued that financial or economic signals do not change long-term attitudes and actions towards environmental activities, while Wilson and Hart (2002) criticise agri-environment scheme evaluations that do not account for the quality of the environmental good, nor how they contribute towards environmental thinking amongst farmers.

Succession and Society

Other, non-production factors play a role in determining farm performance, including adaptation to new practices and business planning being linked to the presence or absence of a successor (Wheeler *et al*., 2012). Shucksmith and Ronningen (2011) argue that societal benefits of small farms in agricultural and rural communities should be considered as a feature of 'performance', rather than assessments being universally driven by efficiency and scale considerations. Sutherland and Burton (2011) similarly argue that the notion of 'good farmers' should be encompassed within the concept of the local and wider social outputs that farmers provide. Stock's (2007) examination of the concept of a 'good farmer' includes the role of identity on their motivations.

Adaptation Strategies

Adaptation strategies, particularly with respect to family farm business survival, have been explored within the concept of 'farm adjustment strategy' (Evans, 2009) which is arguably predicated upon a form of farmer segmentation analysis (Marsden *et al*., 1986). Agricultural business adaptation has also included examination of farm-diversification projects, however, land tenure status has been identified in playing a role in determining diversification practices beyond contract / hire works services (Maye, *et al*., 2009).

Summary and Objectives

Hence, whilst considerable research exploring aspects of farm or farmer performance has been undertaken, frequently studies have arguably been conducted within research 'silos' (Wilson, 2011). Securing a competitive and environmentally sustainable agricultural industry represents a key policy need, encompassing identification of actions and characteristics associated with high performing agricultural businesses. This paper seeks to identify drivers associated with different farm business performance groups drawing upon qualitative approaches within a defined quantitative setting. Section 2 presents the methodological approach followed whilst section 3 provides the case-study results and discusses these in the context of previous research. Section 5 provides concluding comments.

2. Methodology

Following previous research approaches (e.g. Brandth and Haugen, 2011), in-depth case study interviews were chosen as an appropriate methodological approach; farmers selected were drawn from the Farm Business

Survey (FBS) research programme for England. The previous section identified a range of issues with respect to classifying farm performance. In particular there is considerable debate on the appropriate financial-based metrics that can be utilised. Within this study, farm performance was defined in line with the contemporary analyses undertaken by UK farm business government policy analysts. Farm Business Income (FBI) represents the profit generated by a farm business, including direct costs and revenues incurred and accrued by the business, but excluding opportunity costs of owned land and the value of farmer labour. FBI includes the revenues and costs associated with agriculture, subsidies[2], agri-environment schemes and diversified activities. FBI represents a key policy metric of interest within the UK's Department for Environment, Food and Rural Affairs (Defra) providing a comparable metric of business performance to other business sectors. Data was obtained from the English FBS 2006/07 to 2010/11. In order to negate farm-size and farm type (e.g. broad land quality and systems) effects, FBI per hectare (FBI/ha) within farm type groups was used as an appropriate performance metric. Farm businesses were categorised as 'high' (consistently in the top third of the within farm type performance band) or 'improved' (showing an improvement in performance over the five year period) businesses within farm type groups for the purpose of case-study identification. Only farm businesses that co-operated in the FBS throughout the 2006/07 to 2010/11 period were considered, with analysis restricted to FBS farm businesses covered by the Rural Business Research (RBR) Units of Askham Bryan College and the universities of Nottingham and Reading[3]. Table 1 provides details of the 24 farm businesses sampled according to main farm type and performance group.

Each FBS co-operator invited to take part in the interviews was initially contacted by letter, prior to follow up contact via telephone to establish willingness (or otherwise) to take part. Following agreement to co-operate, a mutually convenient time between the co-operator and the Research Officer (RO) was established for an on-farm visit. A questionnaire format was used in the semi-structured in-depth interviews. To achieve consistency of interview approach the majority of the interviews were undertaken by three ROs in each unit and it was further stipulated that ROs should not interview farms with which they had 'prior knowledge' through their involvement in the FBS. Interviews took place during January and February 2012. The semi-structured format of the interview facilitated open discussion to fully understand the farm-level decision-making behaviour and actions. ROs recorded notes of discussion items during the interview producing comprehensive notes immediately post interview. The on-farm interview focused upon current and past performance, placed in the context of key management decision points (or more regular management decisions) that may explain farm and business performance and efficiency.

The following areas of discussion and data were explored in the interviews; specifically the interviews explored reasons, actions and outcomes with the respondent. Discussion topics and example questions are given [*in italics*]: farm location (*are there any inherent benefits to the location of the farm?*); farm size (*are there any inherent advantages or disadvantages to the farm?*); land quality (*what soil type is the majority of the farm?*); managerial inputs (*what do you do to keep up to date with policy and technical developments?*; *what is your approach to training and qualifications for both yourself and your staff?*); managerial actions (*do you use any benchmarking process? If so what and why?*); education level of co-operator (*highest education qualification, including subject details*); farming business structure (*are you the sole decision maker?; who else is involved?; describe the decision making process*); farmer objectives and goals and outlook for business future (*what are your key objectives, goals or aims in running the farm business?*); barriers and motivations for developing business (*what do you think the prospect are for your farm business and agriculture in general?*); succession planning and inheritance (*is there a clear succession plan for managing the business?*); marketing (*how do you market your various enterprises?*); farmer self-perception of segmentation category (Wilson *et al.* 2013) (Modern Family Business, Pragmatist, Custodians; Lifestyle Choice; Challenged Enterprise). The interviews lasted between one hour and two and a half hours. At the close of the interview a token gift was given to the participating farmer co-operator. In addition to the qualitative data, quantitative data were taken from the FBS record for the farm / farm business on the following areas: diversification activities [percentage revenue from different income streams]; age of co-operator [date of birth]; land tenure [percentage of land owned and tenanted]; farm size [utilised agricultural area (hectares)].

The qualitative data from the interviews were transcribed from detailed interview notes, including quotes from respondents, into a structured word document by the RO immediately following each interview. The structured recording form facilitated thematic analysis of the collated interviews which identified recurring themes and key words within individual sections of the semi-structured interview schedule.

3. Results and Discussion

In most case studies the respondent was interviewed as part of a farming couple, it being usual for both to contribute to the discussion; in some cases other family members were also present. Verbatim quotes from the respondent are shown below in italics with double inverted commas. Tabulated and numeric data are provided to accompany the qualitative results; however these data are not statistically validated hence readers should not make direct inferences from data presented but view them as facilitating the presentation of the qualitative material.

[2] Subsidies are dominated by the Single Farm Payment (SFP) which over the period of data examined was increasingly based upon the flat-rate area payment; hence examining performance on a per hectare basis largely negates the influence of the SFP on FBI/ha metrics as all farmers were in receipt of the SFP.

[3] These RBR Units undertake the FBS within the counties of Berkshire, Buckinghamshire, Cheshire, Derbyshire, Gloucestershire, Hampshire, Hereford, Isle of Wight, Kent, Lancashire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Oxfordshire, Rutland, Shropshire, Somerset, Staffordshire, Surrey, Sussex, Warwickshire, Wiltshire, Worcestershire and Yorkshire.

Table 1: Number of Farmers interviewed by Main Farm Type (MFT) and Performance Group

Main Farm Type	High Performers	Improved Performers
Cereals	2	3
General Cropping	2	2
Dairy	3	2
Lowland Grazing	3	2
Less Favoured Area (LFA) Grazing	2	3
Total	12	12

Farmer Characteristics and Decision Making Processes

Twenty-two of the case-study respondents were second or third generation farmers, with only two being first generation farmers. Typically the current farm holding had been in the family for several generations. The oldest (youngest) respondent was 74 (35) years of age; the distribution of ages and length of time the respondent had been managing the farm are closely linked (Table 2). One quarter of respondents had obtained no qualifications since leaving school, but typically respondents had attended agricultural college and obtained either City and Guilds or diploma qualifications, with educational achievement being reflective of the ages of the respondent being interviewed. Previous analyses have not identified education as a significant determinant of efficiency (Wilson *et al.*, 2001), albeit that age is partly indicative of educational level which Wilson *et al.* (1998; 2001) and Hadley's (2006) analyses identified as inversely related to efficiency. A higher proportion of older farmers were observed in the high performance group relative to the 'improvers' performance group; the influence of age or life-stage on managerial actions and performance has been previously cited as of behavioural importance and in self-segment categorisation (Dwyer *et al.*, 2007; Plummer, 1974; Wilson *et al.*, 2013), together with having relevance for policy makers (Moon and Cocklin, 2011).

Three of the 24 respondents could accurately be described as 'sole-decision makers'; however, most typical was the situation where the farming couple run the business together with decisions being made jointly, frequently via informal discussions occurring during the course of a normal working day. A key feature of the majority of the sample was that, regardless of whether they took advice or not, responsibility for decisions lay with the respondent or the farming couple. With respect to the advice sought, most respondents reported the importance of reading the farming press, with a proportion also mentioning use of electronic media to keep up-to-date with technical developments. These differences in preferred sources of advice reflect the variety of media of communication preferred by different farmer groups (Wilson *et al.*, 2000). Most arable respondents mentioned the key role of the agronomist, reinforcing Wilson *et al.*'s (2001) identification of 'information seekers' as more technically efficient wheat producers; livestock respondents were much less likely to use a regular visiting specialist. Respondents who attended discussion groups noted how vital and useful these are as a mechanism to keep up to date, whilst non-attendees were critical of such groups citing them as:

"*too long-winded*" [or] "*not of benefit to the business*"

Contrasting with these critical attitudes towards discussion groups, Barnes *et al.* (2011) reinforce the importance of information seeking and collaborative networks in determining performance. However, many respondents stated they would attend one-off meetings of a technical nature and open days were seen as a key way of keeping up-to-date with training especially with regards to health and safety and cross-compliance. The majority of respondents did not participate in crop or livestock competitions, frequently citing lack of time or lack of value to the business. These differences in attitudes towards networks and sources of advice are argued here to reflect differences in the intensity of engagement and interaction in networking (May *et al.*, 2011). Seventeen farmers reported that they used benchmarking, with the majority of this sub-group specifically referring to the FBS (from which they receive feedback as part of their co-operation). While the overall sample is argued to be more aware of benchmarking as a business management process because of their involvement in the FBS research programme, six respondents specifically emphasised the value of benchmarking services in addition to the FBS. These systems were generally enterprise specific such as those for vining peas or sugar beet or livestock data such as those provided by EBLEX[4]. Accepting the caveat that the respondents are more aware of benchmarking services because of their involvements in the FBS, use of these additional benchmarking facilities arguably reinforces previous findings with respect to the importance of benchmarking as a managerial process (Wilson, 2011; Langton, 2012). Business benchmarking also facilitates managers in identifying areas of success and need for improvement (Langton, 2012); Gloy *et al.* (2002) found that the use of external record keepers was positively correlated with farm performance.

Respondents with livestock were either fully committed to marketing deadweight or to the auction or used a mixture of both. Respondents with arable farms generally sold through merchants with some preferring contracts, others relying on the open market, with others noting the importance of selling to more than one merchant in order to take advantage of better prices and also to spread risk. However, some respondents sold some of their crops through a marketing group (such as potatoes; cereals) and the rest through merchants. Respondents from dairy farms all sold to wholesalers although one was hoping to sell to a local buyer who needed milk for a cheese contract. Respondents with a diversified activities used specific marketing channels to promote these enterprises, including internet and

[4] English Beef and Lamb Executive. Levy-funded board undertaking research and development activities alongside market intelligence functions. http://www.eblex.org.uk/

Table 2: Age Group, Managerial Experience, Qualifications, Tenancy Status, Farm Size and Key Advice against High and Improved Performance Classification

	Category	High Performers	Improved Performance
Age Group	71+	1	-
	61–70	4	2
	51–60	3	6
	41–50	3	2
	<40	1	2
Length of time (years) managing farm	>30	3	4
	20–29	8	2
	10–19	1	4
	<10	-	2
Qualifications	Nil	4	2
	City and Guilds	1	4
	NCA, HND	5	5
	Degree	2	1
Tenancy Status	Owner occupier	4	3
	Tenant	3	5
	Mixed tenure	5	4
Farm Size (ha)	<100	5	1
	101–200	5	4
	201–400	2	5
	>401	-	2
What key advice would you give? [*note that some respondents provided more than one key piece of advice*]	Control costs	5	5
	Pay attention to detail/focus on key things	4	3
	Be flexible/ open to change/ look for new opportunities/ react to change fast	2	2
	Look after cows and they will give you profit	1	2
	Get the right people around you	1	1
	Do not buy in livestock as it leaves you open to disease	-	1
	Develop a range of income streams	-	1

doorstep magazine advertising, for example in farm-food retailing ventures.

Farm Characteristics

There was a broadly equal distribution across the tenure types of farm businesses interviewed, with the sample being over-representative of tenant and mixed tenure farms (Table 2) in comparison to the overall FBS sample. Farms in the improved performance sample tended to be larger in size (average 239 ha) than those in the high performing band (135 ha), only partially explained by the LFA farms which were small in area for the high performers and much larger in area for the improvers. Whilst previous studies have observed a positive correlation between efficiency and farm size (Wilson *et al.*, 2001; Langton, 2012), others have identified that the best small farms achieve greater efficiency than a number of large farms (Langton, 2011). Most of the farms utilised family labour only, with only seven farms using paid labour, reflecting the farm types with dairy farms typically employing labour and low-land grazing or LFA farms typically not employing labour; one-half of the farms employed contractors or casual labour. Criticisms of previous efficiency and performance analyses include lack of data on the land and situational factors of the farm business (e.g. Wilson *et al.*, 1998). Respondents were therefore asked to consider whether their current farm holding provided any inherent advantages or disadvantages; nearly all answered in terms of soil types and rainfall with other factors such as proximity to markets and support services also cited.

Farmer Objectives and Attitudes

Making profit was mentioned as a common objective. However, the majority of respondents qualified their answers with comments concerning family objectives or lifestyle, but the importance of profit remained:

"*make a profit – everything geared towards maximising profit and minimising risk*".

This finding with respect to the importance of objectives in determining performance concurs with Wilson *et al.*'s (2001) analysis of determinants of efficiency. Achieving profit within family objectives / lifestyle, risk minimisation, and focusing upon margins were equally noted as important drivers in other research (Robinson, 1991; Defra 2008; Wilson *et al.*, 2013). A number of respondents emphasised (product) *quality* and *margins* rather than profit *per se* as a key objective. Several livestock farmers recognised that the recent improvement in livestock prices had enabled them to achieve a better life/work balance. Indeed, the need for policy makers to understand financial drivers alongside wider attitudes, behaviours and actions has been well documented within non-productivist frame-works (Siebert, *et al.*, 2006; Burton, 2004; Defra, 2011a). Dairy farms typically emphasised objectives that were specific to their cows – e.g. improve efficiency, achieve better milk quality, improve the healthiness of the herd. Arable farmers were typically aiming for high margins as distinct from high yields; monitoring input costs was critical to achieving this.

With respect to self-segmentation analysis (See Wilson *et al.* 2013) two-thirds of those interviewed regarded themselves as 'pragmatists'; one-quarter as 'custodians' and two farmers felt they fitted the category of 'modern family business'. Of the 24 respondents interviewed for this study, ten had previously been interviewed for the segmentation study (Wilson *et al.*, 2013); of these eight respondents classified in exactly the same way as their previous self-selection (during 2010), whilst one respondent self-classified as a 'Pragmatist' (previously a 'Lifestyle' choice), and one respondent self-classified as a 'Custodian' (previously a 'Pragmatist'). A number indicated that farming was:

"*a way of life*" [or they] "*could not think of another career*"

Borrowings and Performance

The group of high performing farms was characterised by very low levels of borrowings, with only two farms having significant long term borrowings, both relating to land purchase, whilst the most common form of borrowing was the use of higher purchase (HP) facilities for machinery purchase. Incidence of borrowings was higher in the improvers group, where long term loans for land purchase and other major investment (e.g. wind turbines), HP for machinery, and bank overdraft facilities for general running costs typified borrowing activities. All the farmers appeared to have their borrowings well under control and were comfortable with the arrangements in hand for re-paying borrowings. Previous research in the UK has identified the link between debt and farm economic size (smaller farms holding lower debt) (e.g. Langton, 2011) and low debt correlated with technical efficiency (Hadley, 2006; Barnes *et al.*, 2011; Langton, 2012). Gloy *et al.*, (2002) found that the proportion of debt used by New York dairy farms was negatively linked to performance. However, within the Dutch arable sector, Zhenghei and Lansink (2006) identified that debt levels have no influence on financial returns, while long-term debt has a positive effect on productivity growth. Shadbolt (2012) found no link between ability to service debt and farm business performance in New Zealand dairying. The lack of clear causality in the debt-performance debate reflects the different uses of debt: more profitable businesses can service debt and will use these funds to expand, while less profitable businesses utilise debt as a necessity for business survival (Gloy *et al.*, 2002). Hence, both upside and downside impacts of debt are likely to be observed across any sample of farm businesses.

Business Performance and Advice to Others

When asked to identify key aspects to their performance, responses such as 'improvement in prices' 'control of cost', or 'attention to detail' were frequently cited (Table 2); a typical response for the latter was:

"there's so many little aspects to it you can't help improving if you put some effort in. The challenge is to maintain the attention to detail when you increase [dairy cow] *numbers."*

The majority (70%) of the respondents indicated that high yields (e.g. tonnes per hectare, litres per cow, lambs reared per ewe or calves produced per cow) were a key objective, in particular on livestock farms, and from improvers rather than high performers. All LFA farmers reported that high yields were a key focus, in particular where environmental schemes restricted the breeding stocking density of the farm. Attention to detail, linked to achieving higher yields and margins and controlling costs (e.g. application of appropriate and necessary crop protection) reinforces Barnes *et al.*'s (2009) potential for improved technical efficiency via input reductions. With respect to providing advice to others, responses largely related to controlling costs and paying attention to detail. Cost control has been previously cited as a key determinant of success (Barnes *et al.*, 2011). Some of the responses accompanying the advice are typified as follows:

"Don't buy something if you can't afford it and don't take money out of the business if you can't afford it."

[Adopt a...] *"Can be bothered rather than cannot be bothered attitude".*

Future and Succession

With respect to plans for the scale of their business over the next five years, a clear difference emerged between the two groups; five respondents in the 'improvers' group indicated they were looking to expand the scale of their farm businesses, whilst none of the respondents in the high performing group noted this intention. This highlights a key feature of the two sub-groups of farms; the high performers group are in a 'steady state' business position, typically not investing heavily in new resources, whilst the 'improvers' group are more expansionary in outlook as equally identified via their business borrowing profile. A small number of the high performers were planning to retire completely. For those wishing to expand, the availability of land was seen as the major limiting factor, whilst tenancy issues, red tape, and planning regulations were also cited as constraints. At the time of the interviews, farming incomes had recently shown signs of improvement; consequently prospects for their own farm and for agriculture in general were typically upbeat and optimistic, with no difference identified between the high and improvers performance groups.

Approximately 25% of respondents in each group have a clear succession plan. Farms without a succession plan included: no family to succeed; family members did not want to pursue a career in farming; the family members were too young to consider putting a succession plan in place. However, succession was of real concern on some of these farms. Others noted the need to provide flexibility for the next generation, appreciating the need for potential changes to the business to accompany succession:

"each generation sees things differently and opportunities are always changing".

The importance of other objectives in farm business decision making frequently includes family and lifestyle considerations (Wilson *et al.*, 2013), including succession (Wheeler *et al.*, 2012). Policy makers should therefore acknowledge the importance of life-stage analysis in policy implementation, whilst appreciating the long-term view frequently held by farmers, including land stewardship, given the importance attached to succession and inter-generational objectives and attitudes (Burton, 2004).

4. Conclusion

Arguably, the UK and European policy environments in the second decade of the 21st Century differ considerably from those present at the turn of the millennium. Given the food shortages and accompanying price spikes of 2007 and 2008, the growing need for land to produce food, fuel and ecosystem services, combined with a growing world population, lead to a need for policy development and implementation that does not separate 'productivist' and 'non-productivist' outcomes, but provides a combination of the two that is increasingly being recognised as 'sustainable intensification'. Farmers will be directed to enhance production activities while reducing input use, lowering greenhouse gas emissions and providing biodiversity and landscape services all set against a changing climate. Successful farm businesses will rely upon technical, business and environmental information from a range of sources to achieve these requirements whilst also meeting their individual contemporaneous and future objectives. These represent grand policy challenges and ones that are potentially much more complex than observed in agricultural history to date. It is clear that financial drivers play a large role in farm-business decision making (Robinson 1991), but equally this is often only a necessary and not sufficient condition to determining multiple actions and outcomes (Siebert *et al.*, 2006). Farmer self-identity (Burton, 2004; Stock, 2007), inter-generational objectives (Wheeler *et al.*, 2012), education (Wilson, *et al.*, 1998) and managerial ability and actions (Wilson, 2011) all inter-link leading to complex and individually well-founded decision making by farmers; the challenge for policy makers is how to understand and respond to these multi-objective drivers and communicate with farmers in order to generate multi-output objectives. In conclusion, whilst individual business managers can adapt their businesses in order to meet the challenges that lie ahead, both UK and EU policy makers should establish policy frameworks for meeting the food-energy-environmental sustainability outcomes that are cognisant of the complex issues involved in contemporary farm business management decision making.

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REFEREED ARTICLE

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Managerial factors affecting post-harvest loss: the case of Mato Grosso Brazil

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ABSTRACT

Increasing demand for food and rising grain prices makes grain loss and waste reduction a topic of great concern. A fundamental question exists: why would a manager permit losses? Unfortunately, the farm manager's role and understanding of harvest and post-harvest loss (PHL) are not well understood due to a lack of research. We argue that that policy makers and equipment manufacturers need to understand how grain loss reduction fits into the farm manager's 'problem', if efficient levels of loss reduction are to occur. We conduct semi structured interviews and a statewide online survey in Mato Grosso, Brazil to better understand the role of management in harvest and post-harvest loss. The survey results: help fill the important knowledge gap about the managerial component of post-harvest loss; provide insights into loss management among farmers running large modern operations in the fast growing tropical regions of the world; and show and explain the weak motivation to reduce current levels of PHL.

KEYWORDS: post-harvest loss; soybean; maize; tropics; management; Mato Grosso

1. Introduction

Agricultural production needs to increase at least 60% over the next four decades in order to meet the future demand for food (FAO 2009). The projections are grounded on a growing population that is expected to reach more than nine billion people in 2050. Prevention of postharvest losses (PHL) is a key component to meet this demand target (Harvey; 1978; Greeley; 1982; Greeley 1986; and U.N. 2011). Approximately 1/3 of the total annual food production fit for human consumption is lost every year worldwide (U.N., 2011).

We broadly define post-harvest loss as grain lost from harvest up until grain is sold to commercial buyers. More specifically for this research we define three stages of PHL: harvest; short haul; and storage. Harvest often relates to combine related losses short haul involves transport from the field to storage or the market; and storage losses are those losses occurring in on-farm storage.

2. Literature review

To date while there is an abundant literature on harvest and storage loss, there is little research on the manager's role in PHL. We argue that the interface between PHL relevant equipment and management needs to be a vital component of PHL loss reduction policy and private sector strategies. Especially absent is research applied to the fastest growing segment of agriculture, emerging market farmers. These commercial production systems often operate in rough tropical environments with minimal infrastructure, and management systems involving significant mechanization and high labour inputs. This research fills an important gap in the PHL literature by providing a better understanding of farmer's perceptions of loss. The specific research questions are: what is a farmer's role in loss management and does measuring loss reduce loss.

Brazil is one of the developing countries in the tropics that has undergone fast agricultural development and continues to raise expectations about the potential growth of global food production. The state of Mato Grosso in the Midwest of Brazil, already the world's leader in grain production, will be responsible for most of the corn and soybean production growth (MAPA, 2012). Located in the Brazilian savannah, Mato Grosso grain production increased 47% (largely due to an incremental increase in land use and productivity), going from 28.1 million tons to 40.3 million tons between 2008 and 2012 (CONAB, 2013).

In addition to the flat topography, warm weather, and regular rainy season, the development of the agricultural sector in Mato Grosso also results from a highly technical cropping system involving soil correction, pest management, and advanced genetics, and large-scale farm production. The average grain farm size is 1,113 hectares (IBGE, 2006), which is considerably larger than the average grain farm size in other Brazilian states. The scale element is pivotal in the analysis of postharvest loss as a dominant new business model is the large-scale farm that operates in low latitude developing countries.

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The small body of literature on the role of management in post-harvest loss centers in Asia and involves small holders. In such cases farming operations are less complex, may involve small scale irrigation, and at times, may be a subsistence activity (Basappa *et al.*, 2007; Begum *et al.*, 2012). Basavaraja *et al.* (2007) determine that the level of losses on rice is negatively associated with age and education and positively related with total production, acreage, and bad weather conditions. Therefore we hypothesize the following:

H_o1: Younger farmers incur more loss.
H_o2: Better educated farmers incur less loss.

Soybean harvest losses mount in tropical settings because producers are torn by wanting to harvest early, but conditions may not be ideal and optimal care may not be possible (Roessing *et al*, 1981). Soybean harvesting loss was first estimated at 12% in Brazil in 1973 in the southern Rio Grande do Sul (see RS in Figure 1) (Dall'Agnol *et al.* 1973). Harvest loss in Brazil has been estimated to be 10.78% in Parana (Mesquita *et al*, 1980), 10.42% in Parana (Finardi and Souza, 1983), and 4.38% in Mato Grosso do Sul (Sobrinho and Hoogerheide, 1998). The national agricultural research agency EMBRAPA though sets the maximum acceptable level of harvest loss at 2.51% (EMBRAPA, 1999).

Magalhães *et al.* (2009) measure the quantitative losses of soybean by varying harvesting speed and machinery type in the state of Mato Grosso do Sul (see MS in Figure 1), and find that the differences in combine operating speed are not statistically significant. They conclude that loss is more a function of poor combine adjustment and maintenance of the grain cleaning system. They conclude that operator training and combine maintenance are important tools to reduce soybean loss. These conclusions are important because of the relatively high volume of labour employed on developing country soybean farms. Likewise, Campos *et al.* (2005) and Ferreira *et al.* (2007) also do not find significant differences in loss by varying combine speed. However, Mesquita *et al.* (2001) evaluate quantitative loss and broken grains by varying the combine speed in Parana (PR in Figure 1) and conclude that losses tend to abruptly increase for speeds higher than 7 km per hour. Based on these findings, the same authors conducted a second study in several states of Brazil, and found that harvest losses also increase with speed (Mesquita *et al.*, 2002).

There are in fact many causes for soybean harvest losses: uneven soil surface; seed quality; weeds; late

Figure 1: Map of Brazil

harvesting; soybean moisture during harvesting; bad machinery adjustment; and carelessness (Embrapa, 1999; Pinheiro Neto and Gamero, 2000). Consequently, it is imperative that soybean producers measure the losses, identify the major causes, and provide proper training to the operators (Pinheiro Neto, 1999; Pinheiro Neto and Troli, 2003). Franz *et al.* (2002) identify obsolete machinery and untrained operators as the main reasons for harvest losses of 3.71%. Therefore, we hypothesize that perceived losses are positively associated with; high harvest speeds, improper adjustment of the combine, poor maintenance, aged equipment, bad weather, pests and disease, poor seed quality, and uneven soil topography.

H_o3: Awareness of high harvest speed as a factor in loss results in lower levels of harvest loss.
H_o4: Awareness of improper adjustment of the combine as a factor in loss results in lower levels of harvest loss.
H_o5: Awareness of poor maintenance of the combine as a factor in loss results in lower levels of harvest loss.
H_o6: Awareness of aged equipment as a factor in loss results in lower levels of harvest loss.
H_o7: Awareness of bad weather as a factor in loss results in higher levels of harvest loss.
H_o8: Awareness of higher levels of pests and disease as a factor in loss results in lower levels of harvest loss.
H_o9: Awareness of poor seed quality as a factor in loss results in lower levels of harvest loss.
H_o10: Awareness of uneven soil topography as a factor in loss results in lower levels of harvest loss.

Identifying the technical causes and levels of harvest loss are difficult because accurate measurement is rare (Greeley, 1982). This is troubling because of the importance of measurement in the management literature (Porter, 2010; Kalkanci, *et al.* 2012) in support of the notion that you can't manage what you don't measure.

The question of measurement is of interest because the sample reflects educated and large farmers that are a subset of all farmers that would be most likely to be aware of the issue of PHL. Shay *et al.* (1993) emphasize that measuring losses might take only 10 minutes, and this attitude is essential to achieving satisfactory combine operation. But according to Greeley (1982):

"To identify the precise cause requires examining one operation, for example different threshing methods, and keeping constant the methods followed in other operation. In the laboratory this is easy; under farm-level conditions it is far more difficult, for example, to ensure that the grain threshed today will be at the same temperature or moisture content as the grain threshed tomorrow" (Greeley, 1982, p.53).

Franz *et al.* (2002) provide the only evidence of Brazilian farmers measuring loss. They find that only 10% of Federal District farmers measure soybean loss. There is a lack of literature connecting the measurement of harvest loss by managers with the level of PHL. The lack of research on the importance of loss measurement stands at odds with analogous contexts such as environmental management. The prevention of a 'problem' requires first that farmers are aware in order then to act with environmental problems such as groundwater pollution or land degradation (Napier and Brown, 1993; Elnagheeb *et al*, 1995; Bayard and Jolly, 2007). In terms of postharvest losses, the awareness of the problem can be associated with the measurement of the loss. Therefore we hypothesize that farmers who actively measure harvest loss better understand the drivers of loss and are more willing to act to solve the problem.

H_o11: Farmers who measure loss achieve lower levels of loss.

Researchers in India identify farm labour as a significant contributor to PHL (Bassappa *et al.*, 2007; Basavaraja *et al.*, 2007; and Begum *et al.*, 2012). Contractors too are thought to have higher levels of loss compared to owner-operators (Campos, 2005). Modern broad hectare farms in tropical regions like Mato Grosso employ significant amounts of labour because of their size. Typical farms in Mato Grosso are hierarchical in their management as farm owners do not operate equipment, as is the custom in the United States. Thus owners in Mato Grosso choose between contractors and employees, when deciding who should operate equipment in the field. Campos *et al.* (2005), study soybean harvesting using machinery age, harvesting speed, and ownership in Minas Gerais, Brazil, in 2002–2003, and find 62% greater losses when using contractors, 4.72% for contract harvesting against 2.92% per hectare when using their own machinery. Silva *et al.* (2002) find a similar result. Both studies reflect agency problems whereby contractors are more careless than employees or the owner-operator. Attention to loss and care in operation increases when farmers operate the combine (Campos, 2005).

These findings of higher harvest losses by contractors diverge from a seven-farmer focus group study we conducted in Mato Grosso prior to implementing our statewide survey on PHL. The focus group reveals three modes of combine operation in Mato Grosso, owner operation, contracting, and employees. The first two are rarely used in the large operations of Brazil because owners manage and do not operate equipment. Contractors find it difficult to assemble the capital necessary to provide high quality and timely service to a typical farm owner in Mato Grosso; especially given the scale of operations, large distances, poor network of roads, and weather uncertainty. Unlike harvesting in higher latitude regions, low latitude farmers often engage in succession cropping systems where a second crop is directly planted behind the harvest of the first crop. As a result farmers' demands on equipment, speed and operating flexibility limit the value or role of a contractor in such settings. Thus we hypothesize that though large farm owners may be more aware of PHL, larger farms incur greater losses due to dependence on hired labour, and scale diseconomies from operating a large organization under difficult conditions. We therefore hypothesize that using contractors is associated with lower losses, as the alternative of using less well trained employees would likely result in higher losses.

H_o12: Larger farms incur greater loss than smaller farms.

H_o13: Farmers who actively engage in contract harvesting incur lower PHL.

A second area of loss relevant to developing country settings is short haul loss. These are the losses from the field either to storage or the commercial elevator. Farmers either move the grain themselves or often hire contract drivers who provide their own trucks. Historically there have been few studies on transportation losses in developing countries (National Academy of Science, 1978; Caneppele et al, 2012). This is especially true for short-haul loss. Short-haul loss is especially difficult to measure because scales are not present in the field to weigh grain prior to departure to storage or a commercial facility. Transportation losses may occur due to poor road conditions, improper truck maintenance, the type of truck body, overloading, inefficient transfer of grain, and negligent or inattentive drivers (Caneppele et al, 2012). These factors are consistent with the factors identified by our focus group farmers, and are hypothesized to be consistent with higher loss levels.

H_o14: Poor truck conditions results in higher levels of post-harvest loss.

H_o15: The lack of attention results in higher levels of post-harvest loss.

H_o16: An improper truck body results in higher levels of harvest post-loss.

H_o17: Awareness of overloading wagons and trucks as a factor in loss results in lower levels of post-harvest loss.

H_o18: Bad road conditions results in higher levels of post-harvest loss.

H_o19: Awareness of poor loading/unloading processes as a factor in loss results in lower levels of post- harvest loss.

On-farm storage serves as a major reducer of harvest loss (Strahan and Page, 2003; Nawi and Chen, 2007). Farmers are able to avoid unfavourable weather by harvesting the first crop earlier and at higher moisture levels (Abawi, 1993). Farmers have a larger window between succession crops when using storage as they can focus on harvesting and planting, and not getting grain to market (Strahan and Page, 2003). Therefore we hypothesize that farms with on-farm storage will incur lower losses.

H_o20: Farms with on-farm storage incur lower PHL.

3. Materials and Methods

We employed a three stage survey process. First, a focus group with seven farmers took place in Mato Grosso in June of 2012 to better understand the nature of PHL perceptions by farmers and help frame an on-line PHL survey instrument. Following the focus group we developed and tested a draft online survey instrument in November 2012. A final survey, with follow up, was emailed in December 2012 to 1,902 farmers listed in the database of the Mato Grosso Soybean and Corn Growers Association (Aprosoja).

Farmers in Mato Grosso had never before been surveyed online. They are also sporadic users of email, and do not use the Internet as their main source of information (Aprosoja, 2013). The response rate is low, 8.3% (158 observations with 94 usable), but important given the lack of research in the area, and the high quality of the sample. The sample is not representative though, as the farm size of the respondents is twice as large as the average farmer in the state of Mato Grosso. The survey results are still of great interest, since these are some of the largest farmers in the world, and their perceptions about PHL are unknown. They are also the thought leaders for the industry and they operate in the largest and fastest growing corn and soybean state (Mato Grosso) in the world. The survey results have application to other high growth tropical regions such as Africa, other parts of Brazil and Latin America, and Southeast Asia, because respondents operate in a tropical region where expansion is occurring most rapidly.

The survey contains 32 questions divided into three sections. Part one asks farmers general information about the farm. Part two focuses on farmer's perception of PHL and the relationship between soybean harvest loss within a succession crop ('safrinha') production system. Finally the last section includes general questions about the respondent.

Male respondents comprise 97% of the responses, which is consistent with previous work that found women only manage 9% of the farms in Mato Grosso (IBGE, 2006). Regarding age, 50% of the respondents are younger than 40 years old, while 47% are between 40 and 60 years of age (Table 1). These age characteristics match an in-person survey conducted by Aprosoja of their membership, where 41% of the respondents were in between 18 to 44 years old and 50% of the respondents were in between 45 and 59 years old (Aprosoja, 2011). In terms of education, 69% of the respondents have a bachelors or graduate degree. The sample from this survey does not represent the average education level of farmers from Mato Grosso. Numbers from the 2006 census show that only 3% of farmers have bachelors or graduate degrees.

Managerial questions were tested during the focus group study. From the semi-structured interviews, three managerial areas emerged as relevant to PHL: 1) whether farmers measure loss; 2) whether farmers engage harvest contractors; and 3) whether the farm has on-farm storage. All the interviews were recorded and transcribed, and involved two researchers at all times.

Among the respondents, 36% measure PHL. Despite being a small number in absolute terms, the level of measurement is a lot higher than previous findings where only 10% of the farmers in the Federal District of Brazil measure loss (Franz *et al.* 2002). Clearly, the rise in grain prices since 2008 would, *ceteris paribus*, make farmers more attentive to PHL. Thus, the low level of measurement in 2001 (Franz *et al*, 2002) may reflect the low value of the grain compared with a survey of farmers in 2012. The model includes measurement as a binary variable to capture the statistical differences in levels of perceived PHL between farms that measure PHL from the ones that do not measure. Note: there is no definitive measure of PHL on our survey farms. The survey asks farmers to state the level of harvest, short-haul, and storage losses on their farms.

Table 1: Summary statistics of selected demographic, managerial and PHL variables

Total number of farmers	94
Number of measurers	34
Number of non-measurers	60
Average loss estimated by farmers (average in %)	10.37
Harvesting Loss (%)	5.68
Short-Haul Loss (%)	2.24
Storage Loss (%)	2.45
Farmer Characteristics:	
2012 Crop year Soybeans Acreage	2,247
2012 Crop year Corn Acreage	1,097
% of area double-cropped	49%
Age (%)	
<40 years old	50%
41 to 60 years old	48%
>61 years old	2%
Education (% of farmers)	
High School	34%
College graduate	72%
Graduate school	1%
Soybean area (% of farmers)	
<500 ha	14%
500 to 1,000 ha	26%
>1,001 ha	61%
% of farmers with on-farm storage	34%
% of farmers contract harvesting	31%
Farmers Perception of factors affecting PHL (% of farmers):	
High operation speed	34%
Lack of adjustments at the platform when needed	36%
Bad weather conditions	57%
Bad truck conditions	62%

The second managerial area of interest concerns the use of contracting. Agency is clearly an important aspect of PHL management. Theoretically, when agents don't directly bear the risk of their actions, performance suffers. Contractors in Mato Grosso may operate harvest equipment with greater care as they are specialists, compared to employees. The current level of respondents contracting for the harvesting operation is 29%.

There is relatively little on-farm storage in Mato Grosso; about 20% (Medeiros and Goldsmith, 2013). Our survey sample is biased towards larger operators who have higher levels of on-farm storage, as 34% of the producers from the sample have storage on their farms.

The survey asks farmers to estimate or state their harvest, short-haul, and storage losses. Special care was taken during the focus group and survey pre-test to clearly define the terms, 'harvest', 'short-haul,' and 'storage.' We test eight causes of harvest loss and six causes for short-haul loss. The respondents ranked causal factors in terms of importance on a scale of 1–8 for harvest loss and 1–6 for short-haul loss. For tractability and analytical purposes category results are combined. A dummy value of 1 was given to an answer falling into harvest loss category values of a 6, 7, or 8 and a short haul value of a 5 or a 6.

Thus, we model farmer's stated levels of post-harvest losses as:

$$(1)\ PHL = \alpha + \beta(Demo) + \gamma(ManagCaract) + \delta(Causes)$$

Where Causes and ManagCaract are vectors of explanatory variables reflecting the causes and associated managerial characteristics, respectively, which might directly affect the PHL loss levels a farmer perceives. Demo is a vector of demographic characteristics associated with levels of loss.

Correlation analysis identifies low levels of correlation among the 14 hypothesized causal factors of harvest and short-haul loss (Tables 2 and 3). All variables with a correlation above .30 were dropped. Thus we drop maintenance (H_o5), seed quality (H_o9), soil (H_o10), and the body of the truck (H_o16). Then a series of reduced form models were compared in an attempt to balance model performance with analytical scope, as degrees of freedom were a limiting factor due to our small sample. Six additional variables were eliminated without reducing the performance of the model: aged equipment (H_o6); natural causes (H_o8); attention (H_o15); overloading (H_o17); road conditions (H_o18); and loading problems (H_o19). The final multivariate linear regression model contains ten variables, three demographic, three managerial; and four causal.

$$PHL = \alpha + \beta_1(age) + \beta_2(education) + \beta_3(acreage) + \gamma_1(measurers) + \gamma_2(contractors) + \gamma_3(storage) + \delta_1(speed) + \delta_2(adjustments) + \delta_3(weather) + \delta_4(truck\_condition) + \varepsilon_i$$

Where:

- Age is the age of the respondent divided into 3 categories (<40 years old, 41 to 60 years old, and >61 years old);
- Education is the level of education separated into 3 categories: (high school, college graduate, and graduate school);
- Acreage is the soybean area in the 2011/12 season in hectares;
- Measurers is a dummy variable taking value of 1 when the producer measures loss;

Table 2: Correlation coefficients among factors affecting harvesting losses

	PHL	H_Speed	H_attention	H_maint	H_tech	H_weather	H_natural	H_seed	H_soil
PHL	1								
H_Speed	−0.16	1							
H_attention	−0.11	0.11	1						
H_maint.	−0.21	0.23	**0.35**	1					
H_tech	−0.01	0.13	0.10	0.16	1				
H_weather	0.23	0.07	0.20	−0.02	−0.06	1			
H_natural	−0.15	0.08	0.12	0.29	0.16	−0.12	1		
H_seed	−0.10	−0.01	0.16	**0.40**	**0.32**	0.08	**0.39**	1	
H_soil	−0.13	0.14	0.28	**0.42**	0.17	0.11	0.24	**0.50**	1

Table 3: Correlation coefficients among factors affecting short-haul losses

	PHL	Sh_truck	Sh_attention	Sh_body	Sh_overload	Sh_road	Sh_loading
PHL	1						
Sh_truck	0.14	1					
Sh_attention	−0.02	0.27	1				
Sh_body	0.05	**0.48**	0.27	1			
Sh_overload	−0.09	0.27	0.16	**0.42**	1		
Sh_road	0.13	0.23	−0.08	0.26	0.10	1	
Sh_loading	−0.05	0.16	0.11	0.19	0.20	0.10	1

- Contracting is a dummy variable taking value of 1 when the producer outsources part of his/her harvesting operation;
- On-farm storage is a dummy variable taking value of 1 when there is storage on farm;
- Speed is a dummy variable taking value of 1 when the respondent considers that high speed is an important factor (survey response of 6, 7 or 8) affecting on-farm loss;
- Adjustment is a dummy variable taking value of 1 when the respondent considers that lack of adjustments as an important factor (survey response of 6, 7 or 8) affecting on-farm loss;
- Weather is a dummy variable taking value of 1 when the respondent considers that bad weather conditions is an important factor (survey response of 6, 7 or 8) affecting on-farm loss;
- Truck condition is a dummy variable taking value of 1 when the respondent considers that the condition of grain trucks is an important factor (survey response of 5 or 6) affecting short-haul loss.

4. Results

The research employs several tests, both parametric and non-parametric, to better understand farmers' perceptions of post-harvest loss. There is moderate consensus as to the causal factors affecting loss as over 70% of the respondents score poor attention to maintenance and bad weather as important causes of post-harvest loss (Table 4). Producers can effect maintenance but have no control over the weather. Interestingly only 60% state that harvest speed is an important factor in harvest loss. This is consistent with the literature, which is mixed with respect to speed being a cause of loss. Also 60% feel that natural causes from insects and other pests are **not** an important cause of harvest loss. Over 70% of the respondents identify poor road conditions as causing short-haul loss. Contributing to the causes of short-haul loss are the condition of the truck and the body type, as over 60% of the respondents identify these causes as important. Respondents identify the loading/unloading process as a relatively unimportant cause of short-haul loss.

The Y intercept of 7.18 from the results of the multiple regression model represents the baseline perceived level of harvest and short-haul loss of soybeans for farmers in Mato Grosso (Table 5). The coefficient is significant at the 10% level and it is similar in level to the findings of previous studies conducted in Brazil. Farmers therefore may actually have a proper understanding of the level of loss, or that such loss levels may be common knowledge. Three factors provide some evidence of the prior rather than the latter. First there is a considerable range of loss estimates across all respondents. The average stated harvest loss is 5.68% and the sort-haul loss is 2.24%, yet the standard deviations are high, 12.6% and 5.1%, respectively. So there does not appear to be common knowledge as to standard loss levels. Second, on-farm measurement by management of loss does occur. A third of farmers do measure loss thus incorporate loss management into their operations.

Third, semi-structured interviews, both with farmers and executives within the corn and soybean association, reveal an understanding that loss is an issue. They note that there is little experience either measuring or documenting the phenomenon of loss. Thus PHL appears to be a relatively new management issue of concern, albeit mild.

Parametrically there is not a statistical difference between those farmers who state that they measure their PHL and those that don't as the coefficient is not significant at the .10 level. Thus our results do not support H_o11 that farmers who actively measure PHL achieve lower levels of loss. The positive sign on the coefficient may imply that those that do not measure may underestimate their loss levels. The non-parametric analysis too does not clearly differentiate between

Table 4: Factors affecting harvest and short-haul Loss

Item	1–4	5–8		Significance
Harvesting factors (1–8)				
High operation speed	35%	***65%***		**Important**
Lack of adjustments at the platform when needed	29%	**70%**		**Important**
Lack of maintenance	45%	56%		Not Significant
Old technology of the combine	40%	*60%*		**Important**
Bad weather conditions	25%	**74%**		**Important**
Natural causes (insects, rodents etc.)	***64%***	38%		**Unimportant**
Bad seed quality	57%	44%		Not Significant
Uneven soil surface	58%	44%		Not Significant
Short-haul (average of scale 1 to 6)	**1–2**	**3–4**	**5–6**	
Truck conditions	18%	21%	***62%***	**Important**
Lack of attention from the truck driver	11%	45%	44%	**Moderately Important**
Type of truck body	14%	20%	***66%***	**Important**
Overload capacity	17%	29%	55%	**Moderately Important**
Bad road conditions	12%	14%	**73%**	**Important**
Loading/unloading process	***35%***	34%	31%	**Moderately Unimportant**

Importance rate is based on a Likert scale (1=not important and 8=very important for harvesting losses and 1=not important and 6=very important for short-haul).

measurers and non-measurers. Analysis across the 14 causal variables shows that only the awareness that the use of old combine technology increases harvest loss, and the lack of attention from drivers leads to high short haul loss differentiates those that measure PHL from those that don't (Table 6). Thus those that measure PHL do not think differently about the causes of loss than those who don't measure.

The coefficient age shows a negative relation with PHL, meaning that the older is the farmer the lower is on-farm loss. This result is consistent with Basavaraja *et al* (2007) and Begum *et al.* (2012). The coefficient though for education was not significant. It was hypothesized that with more education leads to less loss. Our sample is relatively highly educated.

Farmers who have on-farm storage achieve lower post-harvest losses, as expected. The coefficient of −2.71 is significant at the 10% level. This is an important finding for future policies promoting the installation of on-farm storage in Mato Grosso as PHL reduction will be one key benefit. Recent research has indicated a significant shortage of private storage in Mato Grosso (Medeiros and Goldsmith, 2013).

The coefficient for farmers who employ contracting for their harvest operations is positive but not significant. Thus H_o13 is not confirmed; that those that engage in contracting have lower levels of loss. Thus substituting professional combine operators appears to have no effect on loss. The result is consistent with the weak contracting environment present in Mato Grosso. Contracting has proven to be very prevalent, thus successful, in the United States and Argentina, but relatively little used in Mato Grosso. Implementation of a more professional workforce in the form of specialized contactors will not result in lower loss levels in Mato Grosso. Therefore, focusing on training and improved

Table 5: Estimated determinants of loss

	Coefficient	Expected Sign	t	P-Value	Significance
Intercept	7.18		1.88	0.06	*
Age	−1.29	Negative	−2.00	0.04	**
Education	0.76	Negative	0.77	0.38	
Acres of soybean planted	0.00	Positive	−0.22	0.82	
Measure PHL? (dummy=1 if yes)	2.41	Negative	1.57	0.12	
On-farm storage (dummy=1 if yes)	−2.71	Negative	−1.67	0.09	*
Contracting (dummy=1 if yes)	1.60	Negative	1.03	0.30	
High harvesting speed (dummy=1 if yes)	−3.36	Negative	−2.20	0.03	**
Lack of adjustments at the platform when needed (dummy=1 if yes)	−3.48	Negative	−2.19	0.03	**
Bad weather conditions (dummy=1 if yes)	4.31	Positive	2.88	0.00	***
Bad truck conditions (dummy=1 if yes)	2.32	Positive	1.54	0.12	
Significance level	0.00				
Adj R-squared	0.14				

Significance: *** <=.01, ** <=.05, *<=.10.

Table 6: Results from T-test of the means for factors affecting PHL

Item	Measurers	Non-Measurers	Average	Difference	P-Value	Significance
Harvesting factors (average of 1 to 8 scale)						
High harvesting speed	5.44	4.95	5.13	0.49	0.34	
Lack of adjustments at the platform when needed	5.82	5.08	5.35	0.74	0.12	
Lack of maintenance	4.97	4.52	4.68	0.45	0.36	
Old technology of the combine	5.68	4.22	4.74	1.45	0.00	***
Bad weather conditions	6.00	6.00	6.00	0.00	1.00	
Natural causes (insects, rodents etc)	3.76	3.62	3.67	0.14	0.77	
Bad seed quality	4.12	3.97	4.02	0.15	0.76	
Uneven soil surface	4.62	3.83	4.12	0.78	0.11	
Short-haul (average of scale 1 to 6 scale)						
Truck conditions	4.82	4.32	4.50	0.50	0.19	
Lack of attention from the truck driver	4.71	4.08	4.31	0.62	0.04	**
Type of truck body	5.00	4.50	4.68	0.50	0.15	
Overload capacity	4.53	4.18	4.31	0.34	0.29	
Bad road conditions	4.88	4.88	4.88	0.00	0.99	
Loading/unloading process	3.56	3.27	3.37	0.29	0.42	

Importance is based on a Likert scale (1=not important and 8=very important for harvesting losses and 1=not important and 6=very important for short-haul);
Significance: *** <=.01, ** <=.05, *<=.10.

incentive structures for employees would be more effective for reducing PHL.

Awareness of the connection between high harvesting speed and loss is found to be significant at the .05 level and negatively related to the level of postharvest losses. Therefore farmers who consider that harvesting speed is an important factor affecting harvesting losses achieve lower levels of loss compared to those farmers who do not consider speed to be an important factor.

This would appear to confirm H_o3 that farmers that are more aware of the speed problem are able to reduce their losses, and stands contrary to research denying the linkage between speed and loss.

Similarly the awareness of the importance of combine adjustment for reducing loss is significant at the .05 level and the coefficient has a negative sign. This result not only confirms the hypothesis (H_o4) as to the importance of adjustment awareness for reducing loss, but also supports the general idea that producer awareness of the drivers of loss is an effective loss reduction policy approach. Attentiveness to the role of speed and proper combine adjustment seems to help reduce loss, while having farmers actually measure loss appears to be less important. Speed and equipment maintenance appear to be important areas of focus for training employees and for equipment manufacturers.

Bad weather condition is positively and significantly related at the .01 significance level with loss. Farmers who believe that weather is an important factor affecting PHL incur higher levels of loss. The correlation between weather and speed is quite low, only 0.07. Similarly the correlation between weather versus Operator Attention is also low, 0.20. Farmers have responsibility for harvest speed and operator attention, but do not control the weather. Farmers who cite 'controlled factors' as more important causes than 'non-control factors' achieve lower levels of loss. Therefore farmers that identify management as a way to reduce PHL, are more active in PHL reduction, and as a result incur lower levels of loss. So while PHL reduction is clearly not a high priority for managers, it is a management issue and will respond to policy and industry efforts in support of management oriented approaches to loss reduction.

Finally, as stated above, there is weak consensus as to the causes of short-haul loss. The short haul variables perform poorly in the model, thus many were dropped. Truck condition is the only short-haul variable tested. The positive sign is as hypothesized but the coefficient is not statistically significant. The weak results are puzzling as short-haul loss is known and literally quite visible along farm and rural loads. But there is no research on the topic, as admittedly it is difficult to conduct.

5. Discussion

The specific research questions are:

- What is a farmer's role in loss management?
- Does measuring loss reduce loss?

Implicitly though we ask whether PHL is important to farmers. Clearly the global community cares about PHL, and its reduction. But unexplained is why a farmer accepts controllable loss. Addressing the loss acceptance question would benefit from further research.

The sample is fairly homogeneous and reflects a well-educated and successful set of farmers. The lack of power in the model may better indicate a lack of managerial focus or criticality of PHL to farmers. We posit that challenges of quickly harvesting large tracts of land with extensive weather uncertainly, and heavy use of labour trump attention to PHL levels in the 10% range. Clearly not all loss is measurable, i.e. short-haul, thus remains an abstraction. Also not all loss is controllable, i.e. weather, thus some sources of loss are not a domain of management. The cost of reducing loss further, using current technology, may exceed the benefits. Similarly, the weak results of the model might indicate to policy makers and equipment manufacturers that farmer willingness to pay or invest in loss reduction may be weak. Low cost investments might be acceptable, but specific capital expenditures or those incurring additional labour allocations might involve costs that exceed benefits.

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Profitability and efficiency of cassava production at the farm-level in Delta State, Nigeria

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ABSTRACT

The present study examines profitability, technical, cost and allocative efficiencies of cassava production by applying Data Envelopment Analysis (DEA) of 315 farmers from three regions of Delta State, Nigeria. Results revealed that cassava production was profitable (overall profit margin 1.93), with significant differences across regions as well as farm size categories. Mean levels of technical, cost and allocative efficiencies are low estimated at 40%, 29% and 73% respectively, also with significant differences across regions as well as farm size categories. The implication is that cassava production can be increased substantially by reallocation of resources to optimal levels, given input and output prices. The results also confirmed inverse size-productivity and size-efficiency relationships in cassava production, i.e., the marginal farms are the most productive, profitable, and efficient. Subsistence pressure significantly reduces technical and cost efficiency. Extension contact significantly improves allocative efficiency whereas it reduces technical and cost efficiency. There is no gender difference in performance implying both men and women performs equally well. Farmers located in Delta South and Delta North are technically efficient relative to Delta Central. However, farmers located in Delta North are allocatively inefficient. Investment in extension services to make it more effective and improvements in infrastructure are suggested as policy options.

KEYWORDS: Profitability analysis; technical, cost and allocative efficiency; DEA; cassava production; Delta state; Nigeria

1. Introduction

The agricultural sector in Nigeria is the major employer which employs nearly 70% of the country's labour force (Abolagba *et al.*, 2010; Ismaila *et al.*, 2010; Abolaji *et al.*, 2007). The sector is characterised by small scale traditional farming methods with very low levels of mechanization and modern technologies leading to low levels of productivity (Abang *et al.*, 2000). The growth in the agricultural sector has been slow, growing at an annual rate of 3.7% to 6.5% during the period 2001–2012, which is about half of the GDP growth rates (Eboh *et al.*, 2012; CBN, 2011; Samuel *et al.*, 2010).

Cassava is an important crop that has great potential to support agricultural growth in Nigeria because of its wide range of use spanning from consumption to industrial use. Africa produces 40–50% of the world cassava output (FAO, 2005; Nang'ayo *et al.*, 2007) and Nigeria and Ghana are the leading producers (Ayoade and Adeola, 2009; Knipscheer *et al.*, 2007; Nweke, 2004). In addition, recent studies have shown cassava to be a promising crop for international trade. Indeed, demand for cassava derivatives such as starch, gari (a type of processed cassava), tapioca, etc., were doubled over the last two decades (Nweke 2004).

However, the average yield level of cassava in Nigeria is low estimated at 14.7 mt/ha (Nang'ayo *et al.*, 2007) as compared with 19 mt/ha in Indonesia, which is also a tropical country where production is similarly constrained by low level of input use, high variability in commodity prices, and lack of adequate infrastructure (Sugino and Mayrowani, 2009). To a large extent, the influence of these constraints could be reduced by changes in the use of modern inputs (e.g., fertilizers and pesticides), changes in tenancy policy, and the use of embodied technologies (Oyewo, 2011).

An important factor that affects productivity in developing country agriculture is farm operation size. The debate on size-productivity relationship is mixed in the literature. An inverse relationship between farm size and productivity is prominent in areas where farming practice is labour intensive because, for the large farms, high level of labour costs deters them to use hired labour to optimal levels (Niroula and Thapa, 2005). However, with increased use of modern technology and inputs, the inverse size-productivity relationship has been

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weakened in recent times (Ram *et al.*, 1999 cited in Niroula and Thapa, 2005). Nigerian farming is characterized by small scale and labour intensive farming but large farmers are also featured to some extent. For example, Apata *et al.* (2011) noted that three percent of farm holdings are owned by large farmers with an average farm size of 13.51 ha. Therefore, it is important to test the size-productivity relationship in Nigeria using recent evidence, which this study is set to examine.

According to Ogunsumi *et al.* (2010), past success of the Agricultural Development Projects (ADP) in Nigeria were based on the availability of right technology, free access to inputs, adequate market and other infrastructural provisions. Nnadi *et al.* (2013) also noted importance of extension services in providing information on modern technologies and management of farm resources. However, with the withdrawal of World Bank funding, the quality of extension officers' training and their performance in supporting subsequent ADPs are on the decline (Chukwuemeka and Nzewi, 2011; Adebayo and Idowu, 2000). Nevertheless, the role of extension services cannot be undermined in the pursuit of improving productivity and efficiency in agriculture.

A number of studies looked into production efficiency of cassava in different states of Nigeria (e.g., Oladeebo and Oluwaranti, 2012; Raphael, 2008; Udoh and Etim, 2007; Ogundari and Ojo, 2007). All of these studies applied parametric approach, i.e., Stochastic Production Frontier approach with relatively smaller sample size ranging from 100–200 farmers. It is well known that although parametric approach has certain advantage of accommodating statistical noise, it requires assumption of the nature of production technology and behaviour of the market if cost and allocative efficiencies are to be analysed as well (e.g., Ogundari and Ojo, 2007). Furthermore, all of these studies used the restricted Cobb-Douglas specification of the production technology (without investigating alternative specifications) which imposes unitary elasticity of substitution as well as no interaction amongst inputs and may not represent the true form of underlying technological relationship. On the other hand, the non-parametric approach, i.e., the Data Envelopment Analysis (DEA), does not require any assumption of the production technology or the behaviour of the markets, but all noise and statistical errors are included as inefficiency. Another potential limitation of DEA is the failure to rank the most efficient Decision Making Units (DMUs) leading to possibility of some inefficient DMUs appearing as better overall performers. However, such weakness is unlikely to override the advantage of DEA, particularly, if these DMUs are very few in numbers in relation to total sample size.

Ogundari and Ojo (2007) estimated technical efficiency (TE), allocative efficiency (AE), and cost efficiency (CE) levels of 90%, 89% and 91% for cassava production in Nigeria. Similarly, Oladeebo and Oluwaranti (2012), Raphael (2008) and Udoh and Etim (2007) reported TE levels of 74–79% for cassava production in Nigeria. However, none of these studies examined the size-productivity and/or size-efficiency relationships in cassava production which may be an important limiting factor in assessing potential to improve farmers' performance.

Given this backdrop, the objectives of this study are: (a) to determine profitability of cassava production by farm size categories, (b) to estimate technical, allocative and cost efficiency of cassava production by farm size categories, and (c) to analyse the socio-economic determinants of technical, allocative and cost efficiency of cassava production.

The contribution of this research to the existing literature are three fold: (a) the study specifically tested the role farm operation size on the aforementioned objectives in order to test the size-productivity and size-efficiency relationship with respect to cassava production in Nigeria, which was not addressed in the previous studies; (b) use of the non-parametric DEA approach to estimate all three measures of efficiency simultaneously which then provides information on the potential to improve productivity of cassava without resorting to additional use of resources given existing levels of input prices; and (c) use of the fractional regression model to analyse the socio-economic determinants of observed efficiency levels.

2. Methodology

In order to examine profitability of cassava production, the standard gross margin analysis is used where costs of all family supplied inputs were imputed with market prices. Next, to estimate technical, allocative and cost efficiency of cassava production, DEA method is applied. And finally, to identify the determinants of DEA efficiency scores, a fractional regression model is estimated in the second stage. The details of the methods used are presented below preceded by a description of the study area, sampling procedure and the data.

Study area, sampling procedure and the data

Data used for the study were drawn from the three geopolitical zones of the Delta state of Nigeria which is situated at the South-southern (Niger Delta) part of Nigeria. These are, North, Central and South Delta. The Atlantic Ocean forms southern boundary of the state with a coastline of 160 kilometres. The state has two agro-ecological zones: riverine and upland; and consist of three vegetation types which include mangrove salt swamp areas (mainly in Delta South), rainforest areas (in Delta Central) and upland areas (in Delta North). The annual rainfall varies from 2,665 mm at the coast to 1,905 mm in the inner areas, with average temperature range from 30°C to 34°C. The major food crops grown in Delta state are cassava (leading producer), yam, plantain, maize, and vegetables (MANR, 2006).

Delta state was selected as the case study area due to a number of reasons. Cassava grows best in areas where annual rainfall is about 1,000–2,500 mm and is well distributed, as in Delta state. It can tolerate drought and may even survive 4–6 months of dry weather, provided that such dry weather does not occur too soon after planting. Because of its drought tolerant nature, cassava can grow in areas with as little as 600 mm annual rainfall (Erhabor *et al.*, 2007). Cassava does require some period of dry weather during maturity before harvesting. Delta state has the ideal climatic and soil conditions for the cultivation of cassava and it is a very important crop in the state because of its use as a staple food.

Farm sampling was based on the cell structure developed by the Agricultural Developmental Programme. First, nine local government areas (LGAs) of the total 25 LGAs in the state were selected randomly. Then three cells per LGA were chosen randomly. Next, 105 cassava growers from each LGA were selected using a stratified random sampling procedure with cassava farm operation size as the strata. The cut-off points for farm size followed the nationally defined categories (Apata *et al.*, 2011). These are: marginal farms (upto 1.00 ha); small farms (1.01 to 2.00 ha); medium farms (2.01 to 10.00 ha) and large farms (>10.01 ha). This provided a total of 315 cassava farmers as the sample for the study.

For primary data collection, a structured questionnaire was administered containing both open and closed type questions. A team of two research assistants were trained by one of the authors and all three members were involved in collecting primary data using face to face interview method. Demographic and socio-economic information from each of the farm households included information such as age of the farmer, years of farming experience, number of household members, number of working adult household members, level of education (completed year of schooling) of the head of household, cassava farm operation size, contact with extension services and training received over the past one year, and gender of the household head. Input-output data included information on the quantities of cassava output, family and hired labour, fertilizers, pesticides, and seeds used. Also, information on all input and output prices were collected from each farm household based on memory recall of the farmers. The survey was conducted during September to December, 2008.

Profitability analysis of cassava

Profitability analysis includes calculation of detailed costs of production and return from cassava on a per hectare basis. The total cost (TC) is composed of total variable costs (TVC) and total fixed costs (TFC). TVC includes costs of human labour (both family supplied and hired labour, wherein the cost of family supplied labour is estimated by imputing market wage rate), seed, chemical fertilizers, and pesticides. The cost of tractor use (i.e., for ploughing, harrowing, followed by ridging) is counted as the additional hired labour cost attached to these operations because rental charges of only the tractor cannot be isolated. The tractor services are undertaken as contract based on ha of land to be tilled. TFC includes land rent (if owned land is used then the imputed value of market rate of land rent is applied). Although some other capital may have been used, e.g., buildings and farm implements, but the farmers could not recall the actual cost in order to derive a satisfactory depreciation costs involved for these items, and hence not included. The total revenue (TR) is computed by multiplying the cassava output with the current market price of cassava. The elements are computed as follows:

Total Revenue (TR) = Total cassava output * Cassava price

Gross Margin (GM) = Total Revenue (TR)–Total Variable Cost (TVC)

Total Cost TC = TVC + Total Fixed Cost (TFC)

Profit (P) = TR–TC

Profit margin = TR/TC

DEA approach to analyse technical, cost and allocative efficiency

Data Envelopment Analysis (DEA), a non-parametric approach, has been widely applied to measure relative efficiency of decision making units (DMUs) engaged in the production of goods and services (Kao and Hwang, 2008; Charnes *et al.*, 1978). An advantage of DEA is its capacity to analyze multiple output–multiple input production technologies without assuming any functional form or behaviour of the DMUs or markets. The analysis provides DMU specific relative efficiency measures in comparison to its most efficient peers so that one can identify what factors are responsible for inefficient performance of DMUs.

Technical efficiency relates to the degree to which a farmer produces the maximum feasible output from a given bundle of inputs, or uses the minimum feasible amount of inputs to produce a given level of output. These two definitions of technical efficiency lead to what are known as output-oriented and input-oriented efficiency measures, respectively (Coelli *et al.*, 2002). These two measures of technical efficiency will coincide when the technology exhibits constant returns to scale, but are likely to differ otherwise.

In this study, the input-oriented efficiency measures were used because these lead to a natural decomposition of cost efficiency into its technical and allocative components (Coelli *et al.*, 2002). Since most of the sampled farmers have very small areas of land, the technology is unlikely to be significantly affected by non-constant returns to scale.

Allocative efficiency refers to a producer's ability to maximise profit given technical efficiency. It refers to a producer's ability to utilise the inputs in optimal proportions, given observed input prices, in order to produce at minimum possible cost. A producer may be technically efficient but allocatively inefficient (Hazarika and Alwang, 2003). Cost efficiency, also known as economic efficiency, results from both technical efficiency and allocative efficiency. Therefore, cost efficiency refers to a producer's ability to produce the maximum possible output from a given quantity of inputs at the lowest possible cost.

The DEA production frontier is constructed using linear programming techniques, which give a piece-wise linear frontier that 'envelopes' the observed input and output data. Technologies produced in this way possess the standard properties of convexity and strong disposability, which are discussed in Färe *et al.*, (1994). Although such linearity assumption in crop production is criticised as being too simplistic, the use of DEA is quite extensive in analysing performance of DMUs because of its inherent advantages. Also, with low levels of modern input use in small scale cassava production, the decreasing returns to increased investment in modern inputs is less likely to be a critical factor.

The DEA model is used to simultaneously construct the production frontier and obtain the technical efficiency measures. Following Coelli *et al.*, (2002) the general model for data on K inputs and M outputs for each of the N farms is presented. For the i[th] farm, input and output data are represented by the column vectors x_i and y_i, respectively. The $K \times N$ input matrix, X, and the $M \times N$ output matrix, Y, represent the data for all N farms in the sample.

The DEA model used for calculation of technical efficiency (TE) is:

$$\begin{aligned} &\mathrm{Min}_{\theta,\lambda}\ \theta, \\ &\text{Subject to } -y_i+Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0, \end{aligned} \quad (1)$$

where θ is a scalar, N1 is an $N \times 1$ vector of ones, and λ is an $N \times 1$ vector of constants. The value of θ obtained is the technical efficiency score for the i[th] farm. It will satisfy: $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient farm, according to the Farrell (1957) definition. Note that the linear programming problem must be solved N times, to obtain a value of θ for each farm in the sample.

The cost and allocative efficiencies are obtained by solving the following additional cost minimisation DEA problem:

$$\begin{aligned} &\min_{\lambda,x_i*}\ w_i'x_i^*, \\ &s - y_i + Y\lambda \geq 0, \\ &x_i^* - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0, \end{aligned} \quad (2)$$

where w_i is a vector of input prices for the i[th] farm and x_i^* (which is calculated by the model) is the cost-minimising vector of input quantities for the i[th] farm, given input prices w_i and the output levels y_i. The total cost efficiency (CE) of the i[th] farm is calculated as

$$CE = w_i'x_i^*/w_i'x_i.$$

That is, CE is the ratio of minimum cost to observed cost for the i[th] farm. The allocative efficiency (AE) is then calculated residually by

$$AE = CE/TE.$$

Determinants of efficiency: a fractional logit model

Since the DEA efficiency scores are bounded and typically lie between $0 < \theta \leq 1$, the application of standard regression model is not suitable as mentioned earlier in the introduction section. Therefore, the study adopted a fractional regression model introduced by Papke and Wooldridge (2008) which keeps the predicted values of the conditional mean of the fractional response in the unit interval. Ramalho *et al.* (2011) noted that if large proportion of the fractional data (i.e., efficiency scores) strictly lie above the 0 threshold but do not reach the upper boundary of 1, then a one-part analysis of the data is sufficient[3]. Therefore, a single step fractional logit model is applied in this study which was also adopted by Gelan and Muriithi (2012).

In simple terms, the one-part analysis involves only those observations with $y = \in (0,1)$ for which a conditional mean or a parametric model is employed by assuming a particular distribution of the fractional variable (Ramalho *et al.*, 2011). The conditional mean of the dependent variable (i.e., efficiency scores θ) is given by (Ramalho *et al.*, 2011)

$$E(y|x) = G(x\theta) \quad (3)$$

where G(.) is the known linear function satisfying $0 \leq G(.) \leq 1$. The study assumes $G(.)$ to be a logistic distribution function defined as:

$$G(x\theta) = \frac{e^{x\theta}}{1 + e^{x\theta}} \quad (4)$$

The derivative with respect to the index $x\ \theta$ is given by:

$$g(x\theta) = \partial G(x\theta)/\partial x\theta \quad (5)$$

and the link function $h(\mu)$ is given by (Ramalho *et al.*, 2011):

$$h(\mu) = ln\frac{\mu}{1-\mu} \quad (6)$$

The link function $h(\mu)$ is a widely used concept in the Generalised Linear Model (GLM) literature, and is defined as the function that relates the linear predictor $x\theta$ to the conditional expected value (Ramalho *et al.*, 2011):

$$\mu = E(y|x), \text{ i.e. } h(\mu) = x\theta \quad (7)$$

The quasi-maximum likelihood estimation (QMLE) procedure was applied to obtain robust estimators of the conditional mean parameters developed above by using STATA Version 10 software (STATA Corp, 2010).

The following farm-specific socio-economic characteristics were used as regressors to identify the determinants of technical, cost and allocative efficiencies. These are farmers' experience in years (V_1), subsistence pressure (V_2), educational level of the head of the household (V_3), farm size (V_4), a set of dummy variables to identify the following: main occupation is farming (V_5), extension contact (V_6), training received (V_7), credit receipt (V_8), gender (V_9), Delta North (V_{10}), and Delta South (V_{11}). Choice of these variables are based on existing literature and justification thereof (e.g., Gelan and Muriithi, 2012; Aye and Mungatana, 2011; and Coelli *et al.*, 2002).

3. Results

The summary statistics of the sample farms are presented in Table 1. The average farm size is 2.05 ha with similar share of marginal, small and medium/large farms[4]; average level of completed schooling is 6.92 years; average farming experience is 16 years; 35% of farmers had extension contact in the past one year and only 10% received any training.

Profitability of producing cassava

Table 2 presents the results of the profitability analysis of cassava production classified by farm size categories as well as regions. The major cost element is the labour cost (62% of total). Seed cost accounts for 20.9% of total

[3] See Ramalho *et al.* (2010) for detailed discussion of two-part and one-part analysis of fractional response models.

[4] There is only one farm with cultivated land >10 ha. Therefore, the medium and large farms are grouped as one category.

Table 1: Definition, measurement and summary statistics of the variables

Variables	Definition	Mean	Standard deviation
Cassava root tuber	Kg/ha of cassava root tuber produced	12137.35	11498.98
Inputs			
Farm size	Area under cassava production in hectare	2.05	1.71
Fertilizer	Kg of all fertilizers	94.63	175.14
Labour	Person days	212.77	160.90
Seed	Kg	67.59	48.19
Pesticide	Litre of active ingredients	0.70	2.45
Prices			
Land rent	Naira per hectare	4382.54	760.60
Fertilizer price	Naira per kg	142.82	14.21
Wage rate	Naira per day	579.88	110.43
Seed price	Naira per kg	297.40	58.53
Pesticide price	Naira per litre	1614.66	161.84
Socio-economic factors			
Education	Completed years of schooling	6.92	4.98
Subsistence pressure	Number of family members/working adult	1.52	1.17
Experience	Years engaged in farming	16.11	11.63
Delta North	Dummy (1 if Central, 0 otherwise)	0.33	--
Delta South	Dummy (1 if South, 0 otherwise)	0.33	--
Delta North	Dummy (1 if South, 0 otherwise)	0.33	--
Main occupation	Dummy (1 if farmer, 0 otherwise)	0.84	--
Extension contact	Dummy (1 if had extension contact in the past one year, 0 otherwise)	0.35	--
Credit received	Dummy (1 if had received credit, 0 otherwise)	0.29	--
Training received	Dummy (1 if had received training, 0 otherwise)	0.10	--
Marginal farms	Dummy (1 if cultivated area upto 1.00 ha, 0 otherwise)	0.33	
Small farms	Dummy (1 if cultivated area between 1.01–2.00 ha, 0 otherwise)	0.35	--
Medium/large farms	Dummy (1 if cultivated area >2.01 ha, 0 otherwise)	0.32	--
Gender	Dummy (1 if male, 0 otherwise)	0.41	--

cost. The cost of fertilizers, land rent and pesticides account for 8.8%, 7.5%, and 0.8%, respectively. The overall gross margin per hectare is Naira 58,609[5].

Anyaegbunam *et al.* (2010) noted that labour cost varies between 70–90% of total cost and is a critical constraint in smallholder farming which is reflected in this study as well. It should be noted that about half of the labour cost is imputed family labour cost with market wages. This is the closest approximate to cost family labour used in the production process although a well-functioning hired labour market may not be available in all the survey villages in order to reflect true opportunity cost of family labour. The medium/large farms incur significantly higher levels of hired labour, fertilizers and pesticides costs as compared to marginal farms, yet derive significantly lower level of productivity and profitability, which is quite puzzling.

Cassava production is profitable across all farm size categories and regions with significant differences amongst them based on ANOVA analysis. The overall profit margin is 1.93. Table 2 clearly shows an inverse size-productivity relationship with marginal farms being the most productive as well as profitable followed by small farms. Geography does matter. Both productivity as well as profitability is lowest in Delta North, which may be due to variations in the regional characteristics and agro-ecology.

[5] In late May 2014, 100 Naira was approximately equivalent to £0.37, €0.45, and $0.62 (www.xe.com)

Technical, cost and allocative efficiency of cassava production

Results of efficiency estimates using DEA are presented in Table 3 classified by farm size categories and by regions. The overall mean levels of TE, AE and CE are 40%, 73% and 29% respectively, with significant difference across regions as well as farm size categories. The implication is that there is substantial scope to boost cassava production by reallocating resources to optimal levels, given input prices. As with the case of productivity, a clear inverse size-efficiency relationship is observed with marginal farms scoring highest levels of TE, AE and CE. The last row of Table 3 presents the percentage of DMUs defining the frontier, where higher share of marginal farms are defining the frontier. It is somewhat surprising to see that no small farms are on the frontier. Although, some of the medium/large farms are defining the frontier, their share is relatively small and, therefore, is not of any concern. Therefore, based on the results from Table 2 and Table 3, it can be safely concluded that the classic inverse size-productivity as well as size-efficiency relationship exist in cassava production in these sample farms of Delta State, Nigeria.

Among the regions, farms located in Delta South, which is a coastal region, performed better than the other two regions. These efficiency measures presented in Table 3 are quite low compared to those reported for cassava production in Nigeria, where TE were in the range of 74–79% (e.g., Oladeebo and Oluwaranti, 2012; Raphael, 2008; Udoh and Etim, 2007; Ogundari and Ojo, 2007). However, as mentioned earlier, their

Table 2: Profitability of cassava production per hectare (N) by farm size and region

Variables	Region			Farm Sizes Category			Overall
	Delta Central	Delta South	Delta North	Marginal	Small	Medium/ Large	
Cassava root tuber (kg)	6874.38	7283.25	5904.56	8571.56	6351.83	5100.34	6687.39
Cassava output price (N)	16.73	17.29	16.48	17.00	17.02	16.45	16.83
Total revenue/ha(N)	115008.40	125927.40	97307.15	145716.60	108095.48	83900.59	112560.53
Imputed family labour cost	19693.25	19729.24	14348.68	18146.20	18326.62	17245.12	17923.72
Hired Labour cost	14793.06	16015.89	23767.11	17321.92	16951.94	20473.41	18192.02
Total labour cost	34567.77	35621.43	37829.19	35445.67	35179.94	37506.08	36006.13
Fertilizer cost	5366.32	3818.83	6237.75	2564.42	5598.04	7313.22	5140.97
Pesticide cost	411.11	295.04	648.75	431.01	321.73	617.27	451.63
Seeds cost	11931.19	15662.74	9133.24	17225.25	10375.58	9132.36	12242.39
Total Variable Cost/ha (N)	52276.40	55398.03	53848.92	55666.36	51475.30	54568.92	53950.73
Imputed land rental cost	2887.05	3781.67	2131.96	3540.86	3164.68	2045.43	2933.56
Rented land rental cost	1741.50	479.76	2385.47	843.26	1438.92	2362.87	1535.57
Total Fixed cost	4614.29	4271.43	4261.90	4413.46	4360.36	4375.00	4382.54
Gross Margin	62732.00	70529.37	43458.23	90050.24	56620.18	29331.67	58609.81
Profit	58117.72	66257.94	39196.32	85636.78	52259.82	24956.67	54227.27
Profit Margin	2.02	2.11	1.67	2.43	1.94	1.42	1.93

Notes:
1. Significant difference exists across regions for all variables except fertilizer and pesticide costs (based on One-Way ANOVA analysis).
2. Significant difference exists across farm size categories for all variables except imputed family labour cost and Total Fixed Cost (based on One-Way ANOVA analysis).
Source: Computed from Field Survey, 2008.

estimates are based on restrictive Cobb-Douglas stochastic frontier models with relatively small sample sizes, which may be a source of difference.

4. Determinants of technical, cost and allocative efficiency of cassava production

Table 4 presents the parameter estimates of the fractional logit model with robust standard error obtained by applying Quasi-Maximum Likelihood Estimation (QMLE) procedure. A total of 12 variables representing farm-specific socio-economic factors were used to identify the determinants of observed technical, cost and allocative efficiencies of cassava production. The model diagnostics revealed that these variables jointly explain variation in farm-specific efficiency levels quite satisfactorily. A total of 13 coefficients out of 36 in three models (excluding the intercept) were significant at the 10% level at least, implying that these factors exert differential effect on the observed measures of efficiency.

Table 4 clearly shows that marginal farms are more efficient relative to small and medium/large farms which econometrically confirm the inverse size-efficiency relationship observed in Table 3. Subsistence pressure significantly negatively affects technical and cost efficiency. The interpretation is that higher dependency ratio increases inefficiency. In other words, large families with fewer working adults are relatively inefficient because labour available from the family may not have the requisite experience in farming.

Extension contact significantly improves allocative efficiency. However, extension contact also significantly reduces technical and cost efficiency. The implication is that farmers who have extension advice are using the inputs in the correct combination (i.e., improving allocative efficiency) but perhaps using too much of them and not achieving the expected yield (hence technical efficiency is lower). And because the farmers are using too much of the inputs, their cost efficiency is low. Aye and Mungatana (2011) also reported negative significant influence of extension contact on technical efficiency and positive influence on cost efficiency in maize production in Nigeria. They concluded that extension services in Nigeria in general have not been effective, especially after the withdrawal of the World Bank funding from the Agricultural Development Project, which is the main agency responsible for extension services (Aye and Mungatana, 2011). Table 4 also shows that training significantly negatively influence technical and cost efficiency. The reasons may be that the type of training which the farmers received are either not relevant or not specifically on cassava production and only 10% of the farmers have actually received any type of training in the sample. It is disappointing to see no influence of education or experience on efficiency. Gender does not pose any limitation on performance, implying that both male and female farmers perform equally well, which is very encouraging, particularly when 59% are female.

Location of farmers has an important effect on performance. Farmers located in the Delta North and Delta South are technically inefficient as compared with farmers in Delta Central. However, farmers in Delta North are allocatively inefficient. The reasons for such differences may lie with respect to differences in the regional features (e.g., soil conditions, topography, weather, and other unknown factors) and market

Table 3: Technical, cost and allocative efficiency of cassava production by region and by farm size

Regions	Delta Central			Delta South			Delta North			Overall		
	TE	AE	CE	TE	AE	CE	TE	AE	CE	TE	AE	CE
Mean	0.37	0.75	0.28	0.43	0.78	0.32	0.39	0.66	0.26	0.40	0.73	0.29
Std Deviation	0.14	0.12	0.13	0.23	0.18	0.17	0.21	0.18	0.18	0.20	0.17	0.16
Minimum	0.15	0.47	0.12	0.19	0.26	0.15	0.08	0.12	0.06	0.08	0.12	0.06
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
p-value for regional differences (ANOVA)										0.057	0.000	0.011

Farm size categories	Marginal (upto 1.00 ha)			Small (1.01–2.00 ha)			Medium/Large >2.01)			Overall		
Mean	0.50	0.82	0.40	0.34	0.71	0.23	0.36	0.67	0.24	0.40	0.73	0.29
Std Deviation	0.21	0.16	0.17	0.12	0.13	0.06	0.21	0.15	0.19	0.20	0.16	0.17
Minimum	0.24	0.12	0.08	0.17	0.39	0.11	0.08	0.14	0.06	0.08	0.12	0.06
Maximum	1.00	1.00	1.00	0.74	0.99	0.41	1.00	1.00	1.00	1.00	1.00	1.00
p-value for farm size differences (ANOVA)										0.000	0.000	0.000
% of farmers defining the frontier by farm size	7.69	3.84	3.84	--	--	--	6.00	3.00	3.00	4.44	2.22	2.22

Source: Computed from Field Survey, 2008.

conditions (e.g., input prices, timely availability, market infrastructure, market competition, *etc*.).

5. Conclusions and policy implications

The present study examined the level of profitability and technical, cost and allocative efficiency of cassava production as well as determinants of efficiency using a sample of 315 farmers from three regions of Delta State, Nigeria. Specifically, the study tested the hypothesis of inverse size-productivity and size-efficiency relationships in cassava production.

Results confirmed that Nigerian agriculture is still dominated by marginal and small farms accounting for 68% of the total sample which is very close to the national estimate of 70% reported by Apata *et al.* (2011). Cassava production is profitable across all farm size categories as well as regions. The overall profit margin is 1.93 and the average levels of TE, AE, and CE are 40%, 73%, and 29%, respectively, implying that cassava production can be boosted substantially by reallocation of resources to optimal levels, given input prices. The results also confirmed that cassava production in the Delta State, Nigeria demonstrated inverse

Table 4: Determinants of technical, cost and allocative efficiencies in cassava production (fractional logit model with robust standard errors)

Variables	Technical efficiency	Allocative efficiency	Cost efficiency
Constant	−0.6669***	1.0949***	−1.0215***
Delta North§	0.2715**	−0.3581***	0.0816
Delta South§	0.2401**	−0.1234	0.0788
Education	0.0027	−0.0063	0.0026
Main occupation§	0.1597	−0.2004*	0.0396
Subsistence pressure	−0.0689**	0.0148	−0.0542***
Experience	−0.0034	−0.0022	−0.0048
Extension contact§	−0.5565***	0.5866***	−0.2148*
Training received§	−0.2608**	0.0593	−0.2150**
Credit received§	−0.0883	−0.0334	−0.1832
Marginal farms§	0.6925***	0.5834***	0.7839***
Small farms§	0.1361	−0.1117	0.0192
Gender§	0.1117	−0.0005	0.0797
Model diagnostic			
Pseudo log likelihood	−143.68	−124.75	−129.74
AIC	0.9948	0.8745	0.9063
BIC	−1693.73	−1705.04	−1705.33
Number of observations	315	315	315

Note: *** = significant at 1 percent level ($p<0.01$)
**= significant at 5 percent level ($p<0.05$)
*= significant at 10 percent level ($p<0.10$)
§= dummy variables.

size-productivity as well as size-efficiency relationships. The smallest scale farms, i.e., the marginal farms are the most productive, profitable and efficient followed by small farms. In other words, the cassava farming system in Nigeria conforms to the characteristics of regions with inverse size-productivity relationship as outlined by Niroula and Thapa (2005), i.e., dominant labour cost and low levels of modern input use (e.g., fertilizers, pesticides, and modern seeds). Extension contact significantly improves allocative efficiency whereas it reduces technical and cost efficiency. Subsistence pressure significantly reduces technical and cost efficiency. Farmers located in Delta North and Delta South regions are technically efficient relative to Delta Central (the effect of which is subsumed in the constant term). And farmers located in Delta North are allocatively inefficient relative to Delta Central.

The agricultural extension services in Nigeria needs to be revitalized so that it not only supports allocative efficiency but contributes to improving technical and cost efficiency of cassava production for all categories of farmers because mean efficiency levels are still very low across the board. This would require investment in developing capacity of the extension workers on new and improved technologies as well as dissemination strategies so that they can effectively serve to benefit the farmers. Also, measures are needed to target farmers located in Delta Central and Delta North to support them to overcome low level of inefficiency relative to Delta South. This may take the form of providing infrastructural and marketing support to bring them at par with the facilities and opportunities available for farmers in Delta South. Although the policy options are challenging, effective implementation of these measures will increase production of cassava that could contribute positively to agricultural growth in Delta State, Nigeria.

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FARM-LEVEL MODELLING

GUEST EDITORS: CATHAL O'DONOGHUE and URSULA COLOHAN, TEAGASC, IRELAND

The following three articles are based on papers given at The Agri-Food Workshop at the European Meeting of the Microsimulation Association, Dublin, Ireland, May 2012.

Although Cathal O'Donoghue is a co-author on two of the articles, each has been subject to the usual IJAM scrupulous process of double-blind reviewing, revision and re-reviewing, audited by the IJAM Editor.

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REFEREED ARTICLE

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On the dynamics of agricultural labour input and their impact on productivity and income: an empirical study of Swiss family farms

DANIEL HOOP[1], GABRIELE MACK[2], STEFAN MANN[1] and DIERK SCHMID[1]

ABSTRACT

The labour employment trends of 2003 Swiss FADN farms between 2004 and 2009 are studied, differentiating between the use of on- and off-farm family labour, employees, and contracting services accomplished by and for third parties. By means of a correlation and data envelopment analysis, the relationships between changes in labour input, farm size, productivity and income are empirically explored. With the aid of a cluster analysis 7 major strategies to adjust labour input are revealed whereas slightly over half of the farms in the period under consideration leave labour input at a constant level. Although some of the clusters differ substantially in terms of growth in both labour productivity and income, differences in total factor productivity are not significant.

KEYWORDS: On-farm family labour; off-farm labour; employees; contractors; growth; cluster analysis; productivity; DEA

1. Introduction

Over the past few decades, the comparison of different forms of institutionalisation of labour has become a common field of research for agricultural economists, with particular attention being paid to the dichotomy between work performed on one's own farm and that performed off-farm as an employee (Huffman, 1980; Schmitt, 1989; Phimister And Roberts, 2006; Mann, 2007). Another topic that has been addressed is the decision to employ external labour on the farm (Van Zyl *et al.*, 1987; Preibisch, 2007). By contrast, studies on the dynamics of the use of contractors have been pursued less frequently (Krüsken, 1964; Franz *et al.*, 2010).

The three activity spheres involving the use of family labour (family members active on the farm), employees (non-family employees on the farm) and contractors (self-employed partners working on the farm) are naturally interdependent to a large extent, as already pointed out by Beckmann (1997) in a comprehensive paper using transaction-cost theory to deal with the determinants of these three variables on farms. The present article builds on this paper, but is more oriented towards observing empirically the relationship between changes in labour use, farm size, farm income, and productivity. Based on accountancy data from Swiss family farms between 2004 and 2009, it addresses the issue of what patterns are to be observed in the change in labour use over time. When we speak of the need to grow or give way, particularly in agricultural sectors with small-scale family farms (Weiss, 1999; Groier, 2004), this also raises the question of how the three forms of institutionalisation of labour are associated with one another in the growth process. In addition to this, the income and productivity growth that goes hand-in-hand with the individual patterns is considered.

As a general rule, when productivity remains constant, dynamic farm growth entails a dynamic growth in labour input, i.e. a change in farm size also entails a change in labour input. However, the theoretical possibility of leaving the ratio between the types of labour at a steady level is not always realistic in the case of growth and shrinkage processes. Reasons for a change in the composition of the types of labour accompanying farm growth might be that the family labour pool is already exhausted, or that the critical threshold for (additional) employees has not been reached. On the basis of differing flexibility, it is obvious that the variation in working-time requirement can be controlled to especial advantage via contracting services carried out on the own farm or for other farms, provided that there is a supply or demand for this. This assumption, however, requires empirical verification, which is the aim of this study. Although some parts of farming (Beckmann and Wesseler, 2003) or different farming systems (Buduru and Brem, 2007) have been

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looked at from this transaction cost perspective, a holistic view has not been covered yet for family farms.

To start with, the options for controlling the use of family and wage labour on the farm are described in somewhat greater detail in Section 2. Next, Section 3 outlines and substantiates the methodological approach. The results are set out in Section 4, followed by the drawing of conclusions–particularly with respect to the theoretical implications arising from the patterns observed–in Section 5.

2. Operationalisation of Family, Wage and Outsourced Labour

The term 'family labour' is derived directly from the concept of the family farm, and encompasses all the managerial and executive activities of all persons usually belonging to the farm manager's family who do not receive a wage but participate from the family farm income (mainly farm manager, partner, other family members). For a number of reasons, family labour is considered to be particularly favourable: for one thing, family members are themselves interested in turning a profit, and do not incur supervisory charges (Hayami, 2010); for another, family members can be expected to work flexible hours, and because of their spatial proximity and familial closeness incur only minor coordination and adaptation costs (Beckmann, 1997). According to Beckmann (1997), family labour possesses obvious transaction-cost advantages over employees or contractors, particularly in the spheres of business management and animal husbandry, where managerial and executive activities are not readily separable.

Despite this, family labour in Switzerland is also increasingly being deployed off-farm (Lips and Schmid, 2012). This happens both because some family members have a preference for or are better qualified for non-agricultural work, and because the diminishing marginal benefits of employing labour on the family farm make off-farm work more profitable (Schmitt, 1989).

The labour performed on farms by (permanent or non-permanent) employees who regularly receive a wage is termed 'wage labour'. Wage labour involves supervision and orientation costs, a fact which–according to Beckmann (1997)–has a negative impact on productivity (Eastwood, 2010). Moreover, wage labour is associated with a financial risk, since–seen from a short-term perspective–it constitutes a fixed-cost factor. It is therefore to be expected that family labour will be preferred to wage labour, and that wage labour will only be used when there is enough work to fully utilise the latter, or if the family workforce–owing to their high educational level–has markedly higher opportunity costs than wage labour. According to Beckmann (1997), wage labour is especially well suited to performing simple machine tasks, for straightforward manual animal-husbandry tasks, and for simple manual plant-production jobs.

The term 'outsourced labour' refers to those jobs outsourced by the farm to third parties (contractors and possibly also neighbour farms) that are normally invoiced on an area-related or hourly basis. Activities that are only performed occasionally, which can be measured relatively easily ex post in terms of their performance, and which require a high specific human capital (e.g. special machine tasks with a high service requirement and high risk of injury; Beckmann, 1997) are suited to contracting. Here, outsourced labour can take two possible forms for farmers: Either work on the own farm is outsourced, or the farm's own workforce can be used for work on other farms.

3. Empirical Methods

The aim of this paper is to observe empirically the relationship between changes in labour input, farm size, farm income, and productivity growth. Therefore two statistical analyses are carried out. Firstly, a correlation analysis is conducted for estimating the relationships between the above mentioned farm characteristics. Because of non-normal distributions, the Spearman rank-correlations between the different types of labour, the workload on the farm and the turnover of the farm, the family farm income and the productivity growth are calculated. Secondly, farms whose on-farm and off-farm family labour, wage labour or outsourced labour (of and for third parties) changed according to the same pattern are allocated to groups by means of a cluster analysis. Cluster results are then further analysed.

For both statistical analyses a sample of 2003 Swiss family farms which made their data available to the Farm Accountancy Data Network[3] (FADN) in the year 2004 and 2009 (balanced panel) is used.

Measuring labour input, farm growth and farm income

The Swiss FADN system provides the number of family labour units and wage labour units employed on the farm, as well as the number of family labour units working off-farm, in annual working units[4] on a self-disclosure basis. Farm expenditure for labour and machine use by third parties as well as revenues for labour and machine use on neighbouring farms is also available in the FADN system (Table 1).

Furthermore the FADN-data base gives insight in farm income. Since the study is focused on agricultural labour input, the quantification of farm growth refers to the standardised workload on the farm. This indicator provides a suitable and comparable proxy for farm size and changes over time across all farms. The workload was calculated by including all agricultural production activities whose management requires work. Various production activities (e.g. ha wheat, LU dairy cows) were weighted with specific labour standard values (Table 2) and summed up to the farm's total workload. Different standards of facilities or levels of mechanisation which influence the workload required were not taken into account for the above mentioned reason.

[3] Institution for summarizing and analyzing data from farm accountancy departments and supplementary surveys of various data processors for research, education, consultation, determination of the economic status of agriculture, agricultural-policy decision-making and evaluation, as well as agricultural valuation, including valuation for tax purposes.

[4] Both family and external labour units are generally recorded in working days, with an annual labour unit (AWU) corresponding to a fully efficient person working on the farm at least 280 working days per annum. A maximum of one annual labour unit can be credited per person. Part-time employees are converted pro rata on the basis of 280 normal working days per year.

Table 1: Measuring the five different categories of labour input in Swiss family farms

Type of labour input	Short description
On-farm family labour input (AWU)	Family members working on the farm and participating in the family farm income.
Off-farm family labour input (AWU)	Family members working off-farm. Usually as employees in the 2nd or 3rd sector.
Wage labour input (AWU)	Employees working on the farm (permanently or non-permanently).
Expenditure for outsourced work (CHF)	Outsourced work executed by contractors on the farm. Usually invoiced per hour or hectare.
Revenues for labour and machine use on neighbouring farms (CHF)	Work executed by the farm's workforce on neighbouring farms. Usually invoiced per hour or hectare.

Table 2: Labour standard values that were used to calculate the standardised workload on the farms

Husbandry	$h \cdot LU^{-1} \cdot a^{-1}$	Areas	$h \cdot ha^{-1} \cdot a^{-1}$
Dairy Cows*	128	Bread cereals**	43
Suckler Cows*	46	Fodder cereals**	41.8
Calf rearing*	57	Grain maize, pea, sunflowers, soya**	37.6
Fattening cattle*	74	Silage maize**	42
Other Calfs*	150	Sugar beets, fodder beets**	67.7
Horses*	105	Rape**	40.6
Sheep*	111	Potatoes**	150.5
Goats*	248	Grassland**	73.7
Other animals fed with roughage*	111	Fallow land****	11
Breeding sows*	308	Vegetables*	500
Fattening pigs*	38	Tobacco*	809
Broiler chicken*	34	Vineyards*	725
Laying hens*	42	Fruits*	705
		Berries*	2557
		Forest****	25
Additional workload		**Additional workload**	
Due to organic farming***	+20%	Due to organic farming***	+20%
		Due to hillsides***	$42\ h \cdot ha^{-1} \cdot a^{-1}$

Notes: ha: Hectare, LU: Lifestock Unit
***Source:** Deckungsbeitragskatalog 2009, Agridea.
****Source:** Arbeitsvoranschlag 2011 (V 1.1.8), ART.
*****Source:** Preiskatalog 2009, Agridea.
******Source:** Other.

Measuring labour productivity and productivity growth

Labour productivity relates farm turnover[5] to total labour input units (and therefore has the unit $\frac{CHF}{AWU}$) which includes family and wage labour units and expenses for outsourced work[6]. For calculating changes in labour productivity the farm turnover is being deflated on the minimum possible aggregation levels (e.g. revenues from bread wheat/milk/beef/eggs etc.) with price indices from the Swiss Federal Statistical Office in order to minimise the effects of price changes on productivity changes.

Total factor productivity (TFP) is more holistic than labour productivity and defines the ability to convert (possibly several) inputs into (possibly several) outputs. Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are two widely used methods to quantify TFP. We favour DEA over SFA because the distance based non-parametric approach allows to estimate productivity without making assumptions of the production frontier which can crucially influence efficiency scores. The change in TFP was estimated with the aid of the Malmquist Index (MI; Malmquist, 1953; Färe *et al.*, 1992).

$$MI = \sqrt{\frac{d^t_{CRS}(x^{t+5}, y^{t+5})}{d^t_{CRS}(x^t, y^t)} \times \frac{d^{t+5}_{CRS}(x^{t+5}, y^{t+5})}{d^{t+5}_{CRS}(x^t, y^t)}} \quad (1)$$

Where:

in the following 't' is called current and 't+5' is called future

$d^t_{CRS}(x^t, y^t)$ DF[7] with current input-output set x^t, y^t relative to the current technology T^t

$d^t_{CRS}(x^{t+5}, y^{t+5})$ DF with future input-output set x^{t+5}, y^{t+5} relative to the current technology T^t

$d^{t+5}_{CRS}(x^t, y^t)$ DF with current input-output set x^t, y^t relative to the future technology T^{t+5}

$d^{t+5}_{CRS}(x^{t+5}, y^{t+5})$ DF with future input-output set x^{t+5}, y^{t+5} relative to the future technology T^{t+5}.

[5] For comparability with the output specification of the data envelopment analysis, which will be explained in more detail later, direct payments which are not related to ecological services or animal-friendly husbandry are excluded from the total farm turnover.

[6] The costs for on-farm contracting services were roughly converted to AWU by assuming an average price of 160 Swiss Francs per hour (including work and machinery costs), 10 working hours per day and 280 working days per year. The conversion factor from off-farm wage labour costs to AWU is therefore $\frac{1AWU}{448000\ CHF}$.

[7] Input distance function. Reciprocal of the technical efficiency measure proposed by Farrell (1957).

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The four distance functions per farm are calculated by means of linear programming with the input-oriented (CCR) DEA model with constant returns to scale developed by Charnes, Cooper und Rhodes (1978). The distance function $d^t_{CRS}(x^{t+5}, y^{t+5})$ is calculated by the following linear program

$$\begin{aligned} &\left[d^t_{CRS}\left(x^{t+5}, y^{t+5}\right)\right]^{-1} = \min_{\theta,\lambda}\theta, \\ st \quad & -y_i^{t+5} + Y^t\lambda \geq 0, \\ & \theta x_i^{t+5} - X^t\lambda \geq 0, \\ & \lambda, \theta \geq 0, \end{aligned} \quad (2)$$

presented in the so called multiplier form, where:

θ the efficiency of farm i,

λ a I × 1 vector of constants,

x_i^{t+5}, y_i^{t+5} the future $N \times 1$ input vector and $M \times 1$ output vector of farm i,

X^t, Y^t the current $N \times I$ input set and $M \times I$ output set of all farms within the technology T^t and

I: the number of farms, N: the number of inputs, M: the number of outputs in the technology T^t.

As opposed to the original definition, we denote $MI<1$, $MI=1$, $MI>1$ as a decrease, stagnation and increase in productivity, respectively, and present the results as per cent deviation from 1.

The specification of the input-output set is based on Jan *et al.* (2012)[8], who developed an approach adapted to the conditions on Swiss farms. Four input categories (Intermediate consumptions [CHF[9]], Capital [CHF], Labour [AWU], Farm area [ha]), and two output categories (Output from agricultural production + Direct payments [CHF], and Output from agricultural related activities and services [CHF]) are specified. Intermediate consumptions include all direct costs like expenses for fuel, fertilisers, seeds and so forth. Capital costs include depreciation as well as expenses for interests[10]. Labour includes on-farm family and wage labour. The expenses for contractor services were allocated to intermediate consumptions, capital and labour according to an estimated average distribution key[11]. The farm area is made up of the usable agricultural area (UAA) in ha and the agricultural area outside the UAA. Output from agricultural production includes the turnover from selling agricultural products. Direct payments include all payments that are related to ecological or landscape preserving services of agricultural activity as well as payments for especially animal-friendly husbandry[12]. Output from agricultural related activities and services include revenues from the direct sale of products, tourist accommodation and activities but also the theoretical revenues from renting the farm house to the farm manager's family, because of the special accountancy guidelines in Swiss agriculture.

Before the accountancy data was aggregated to the specified inputs and outputs, monetary figures were deflated on the minimum possible aggregation levels (e.g. revenues from bread wheat/milk/beef/eggs or expenses for fuel/mineral fertilisers/seeds/interests etc.) in order to minimise the effect of price changes on productivity changes.

The accountancy sample contains 11 different farm types[13] which are divided among the plain, hill and mountain regions. This yields 33 so-called strata[14], for which the MI must be separately calculated, since the farms evaluated as part of a DEA should be similar (Dyson *et al.*, 2001). The MI calculated within the individual strata were then once again aggregated for the original overall sample.

A drawback of the deterministic DEA approach is that outliers influence the efficiency of other farms. For this reason, in addition to the MI, a 95% confidence interval was calculated for each farm via bootstrapping (Simar und Wilson, 1999; Hall, 1992).

Cluster analysis

A cluster analysis was carried out to identify a limited number of different labour-input strategies–specifically, the most common ones in Swiss agriculture in the past. The aim is to analyze whether these different labour input strategies influence the farms' productivity growth as well as their family farm income. A cluster analysis was favoured over a regression analysis, because the latter could only estimate global dependencies between variables but could not identify typical patterns of labour reallocation which was one of the main goals of this study.

The identified clusters are analysed taking into account

- The clusters' structural features before the labour input change (in the year 2004)
- The clusters' farm size growth
- The clusters' labour productivity growth and the total factor productivity growth.
- The clusters' changes in the family farm income

Changes in how work is organised on Swiss family farms are being investigated with the sample of 2003 FADN farms. The five labour input categories (Table 1) in Swiss FADN-farms formed the underlying data for the cluster process, whose absolute changes from 2004 to 2009 were used as cluster-forming variables. The monetary variables were deflated over the period with the Swiss Federal Statistical Office's key figures. For reasons of data incommensurability (variables have different units of measurement or a mixed measurement level), the data were standardised so that the mean and the variance of each variable was 0 and 1, respectively

[8] For a comprehensive reasoning why this input-output specification was chosen we refer to Jan *et al.* (2012).

[9] In January 2004, 1 Swiss Franc (CHF) was approximately equivalent to €0.64, £0.44 and $0.81 (www.xe.com).

[10] The estimated capital costs for the farm's own land were subtracted in order to avoid a double-counting of the input 'land'. Furthermore, the costs for the leasing of land were not included into capital costs.

[11] The calculations where done according to Swiss farm management literature published by Gazzarin *et al.* (2012). The part that was allocated to labour was converted into AWU as described in footnote 4.

[12] Included are payments for the cultivation of slopes, for the so-called ecological compensation and for the so-called extenso production, for organic production, and for the husbandry according to the guidelines of BTS and RAUS.

[13] according to the FAT99 farm type definition that can be found in Hoop and Schmid, (2013: 11).

[14] Of these 33 strata, only 17 had enough observations to carry out a DEA. Here, the following applies: Minimum no. of observations ⩾ 2 x no. of inputs x no. of outputs (according to Dyson *et al.*, 2001). In order not to exclude too many observations from DEA we slightly changed the specification of the input output set as proposed by JAN *et al.* (2012) from original 4 inputs and 3 outputs to 4 inputs but only 2 outputs (we summed up the output from agricultural production and direct payments). Nevertheless, out of the original 2003 farms in the dataset, only 1912 farms could be analyzed for changes in their TFP.

Table 3: Spearman coefficients of the correlation analysis

changes in...	...labour input					
	Δ on-farm family labour	Δ off-farm family labour	Δ wage labour	Δ expenses for outsourced work	Δ revenues for work on neighbouring farms	Δ wage labour to total labour
Δ on-farm family labour		***−0.18	***−0.21	0	0.02	***−0.38
Δ off-farm family labour	***−0.18		−0.03	−0.03	0	0
Δ wage labour	***−0.21	−0.03		−0.01	0.01	***0.91
Δ expenses for outsourced work	0	−0.03	−0.01		−0.02	0
Δ revenues for work on neighbouring farms	0.02	0	0.01	−0.02		0
Δ wage labour to total Δ labour input	***−0.38	0	*** 0.91	0	0	
Δ workload	*** 0.1	***−0.09	*** 0.12	*** 0.15	−0.03	*** 0.08
Δ turnover[3]	** 0.06	***−0.11	*** 0.16	*** 0.18	*** 0.08	*** 0.12
Δ labour productivity	***−0.32	0.02	***−0.32	*** 0.15	0.03	***−0.23
Δ Malmquist Index	***−0.13	−0.03	−0.02	**0.07	0.04	0
Δ family farm income	*** 0.08	***−0.08	***−0.08	0	*** 0.11	***−0.1
Δ family farm income per Δ on-farm family labour	***−0.33	0.01	0.02	0	***0.08	***0.1

changes in...	...farm growth		...productivity		...income	
	Δ workload	Δ turnover[3]	Δ labour productivity	Δ Malmquist Index	Δ family farm income	Δ family farm income per on-farm family labour
Δ on-farm family labour	***0.1	**0.06	***−0.32	***−0.13	*** 0.08	***−0.33
Δ off-farm family labour	***−0.09	***−0.11	0.02	−0.03	***−0.08	0.01
Δ wage labour	*** 0.12	*** 0.16	***−0.32	−0.02	***−0.08	0.02
Δ expenses for outsourced work	0	*** 0.18	*** 0.15	** 0.07	0	0
Δ revenues for work on neighbouring farms	0.02	*** 0.08	0.03	0.04	*** 0.11	*** 0.08
Δ wage labour to total Δ labour input	*** 0.08	*** 0.12	***−0.23	0	***−0.1	***0.1
Δ workload		*** 0.42	*** 0.17	*** 0.16	*** 0.17	*** 0.1
Δ turnover[2]	*** 0.42		*** 0.59	*** 0.54	*** 0.43	*** 0.35
Δ labour productivity	*** 0.17	*** 0.59		*** 0.55	*** 0.37	*** 0.49
Δ Malmquist Index	*** 0.16	*** 0.54	*** 0.55		*** 0.62	*** 0.64
Δ family farm income	*** 0.17	*** 0.43	*** 0.37	*** 0.62		*** 0.84
Δ family farm income per Δ on-farm family labour	*** 0.1	*** 0.35	*** 0.49	*** 0.64	*** 0.84	

Note: *, ** and *** indicate P-values of 0.05, 0.01 and 0.001 respectively.

(using the ‘scale’ function of R; R Development Core Team, 2011).

For the study, the partitioning k-means method was chosen as an algorithm, since it generates homogeneous clusters with the smallest possible variation within the clusters on account of its optimality criteria. A disadvantage of this method, however, is that it does not permit us to make any assertions about the best possible number of clusters (Bacher *et al.*, 2010). In a first step, 29 cluster solutions with 2 to 30 clusters were generated using the k-means approach. From these, the best possible cluster solution in terms of degree of homogeneity within clusters (compactness) and heterogeneity between clusters (separation), data-assignment quality and reproducibility was selected. The ratio of compactness to separation of a cluster solution is measured on the one hand by the Average Silhouette Width index, and on the other by the Calinski-Harabasz index (Rousseeuw, 1987; Calinski and Harabasz, 1974). The normalised Hubert’s correlation coefficient tests data-assignment quality by measuring the correlation between the cluster allocation and the original distance matrix (Halkidi *et al.*, 2001: 126ff). The larger the correlation coefficient, the better the cluster solution. The reproducibility of a cluster solution is checked with the aid of a bootstrapping method which slightly changes the entire dataset, generates new so-called bootstrap cluster solutions, and calculates the overlap between the original cluster solution and the bootstrap cluster solution with the help of the Jaccard coefficient (Hennig, 2007). As a final criterion, the number of farms per cluster was taken into account. Clusters with fewer than ten farms were excluded. There followed the content check to determine whether the clusters made sense and were plausible, and whether a name could be deduced for as many of them as possible (Bacher *et al.*, 2010). The ‘k-means’ function in the basic R-package was used for the cluster analysis. The starting centres were randomly set at 10,000 repetitions in each case in order to tackle the initial seed problem and to ensure the discovery of a globally optimal cluster solution. Cluster validation was performed with the ‘cluster.stats’ and ‘clusterboot’ functions from the fpc package in R (Hennig, 2010).

4. Results

Correlation analysis

The coefficients of the correlation analysis show the global interdependencies between shifts in the five distinguished types of labour input categories, farm growth, productivity growth, and income change (Table 3). Family labour input on-farm is negatively correlated with off-farm family labour and wage labour input, reflecting the substitutability of the different categories. Farm growth is accompanied by additional input of on-farm family and wage labour as well as on-farm contracting services. Off-farm family labour is reduced whereas off-farm contracting is not influenced by farm growth, meaning that the latter is not used in order to regulate farm labour capacities.

Naturally, labour productivity is negatively correlated with on-farm family and wage labour whereas the positive correlation with on-farm contracting indicates that labour productivity can be raised by employment of professional workforce with high specific human capital. Furthermore, the negative correlation between labour productivity and the share of wage labour at total on-farm labour supports the hypothesis that family labour is more efficient than wage labour.

Regarding TFP, a negative correlation with on-farm family labour and a positive correlation with on-farm contracting can be observed. Interestingly, the share of wage labour at the total labour input does not influence TFP. Focusing on the relationship between productivity and family farm income (per on-farm family labour) our results reveal that labour productivity–as part of TFP–does not influence income to the same extent as TFP does. The relationship between TFP and income, however, is impressively high, indicating that TFP is a key component of farm success.

Results of the Cluster Analysis

Selection of the cluster solution

Figure 1 demonstrates the approach for determining the best-possible number of clusters, showing the Average Silhouette Width and Calinski-Harabasz indices, Hubert's statistic, and the number of clusters with fewer than 10 members. At 9 to 11 clusters, both the Average Silhouette Width index and the Calinski-Harabasz index yield the best ratio between homogeneity and heterogeneity. The normalised Hubert's statistic is maximum in the same range. The contents check yielded 10 clusters, two of which nevertheless had too few cluster members, and were therefore excluded. According to the bootstrapping, clusters 1, 2, 3 and 7 are stable, cluster 6 is relatively stable, and clusters 4, 5 and 8 are fairly unstable (Table 4).

Cluster description

The eight identified clusters illustrate the typical changes in farm and family labour organisation that were observed in the sample (Table 5).

More than half of all the farms belong to cluster 1, for which family labour, number of employees and contracting services both on-farm and off-farm have hardly changed over 5 years. Owing to its relatively stable work organisation, it will hereinafter be referred to as the 'Stable' cluster.

In the second cluster, family members significantly restricted their off-farm labour, but only partially in favour of on-farm labour. This cluster, which contains only five per cent of the farms, is termed 'Sideline dropouts'. Compared to the overall sample, this cluster contains a higher-than-average number of younger farm managers under 35 years of age (28% as opposed to 13%). In 2004, the 'Sideline dropouts' were characterised by well-above-average family off-farm labour, including both the farm manager and his partner. Withdrawal from off-farm labour might therefore be because of the partner increasingly devoting herself to household, family and farm in the period under consideration.

By contrast, the defining characteristic of cluster 3 is that its family workforce was increasingly employed off-farm at the expense of on-farm activities. This cluster is downsizing its farm by 0.05 AWU, which distinguishes it significantly from clusters 1 and 2. Representing 8 per cent of all farms, cluster 3 is described as the 'Sideline-oriented' cluster. There are significantly more smaller farms with less than 20 ha farm area in the 'Sideline-oriented' group (72%) than in the overall survey (50%) making it harder for this cluster to substantially grow than to give way.

In 2009, the 'Family labour-focused' cluster 4 employed significantly more family members than it did in 2004, at the same time reducing its personnel expenditure. Since cluster 4 does not exhibit any special attributes, the reason for the increase in on-farm family labour remains unclear. We can only guess that there were redundant family workforce that were deployed at the cost of the employees.

Cluster 5, the 'Wage labour-focused' farms, increased significantly the number of employees between 2004 and 2009, both to cope with the above-average increase in workload and to take some of the pressure off of the family workforce. A defining characteristic of 'External labour-focused' farms is that they employed an above-average number of family labour units up to 2004. Taken altogether, they represent 9 per cent of all farms.

Cluster 6, the 'Outsourcing-focused' cluster, exhibited above-average growth between 2004 and 2009, making increasing use of agricultural contractors. The 'Outsourcing-focused' cluster is characterised by a high percentage of lowland farms (68%). As early as 2004, both livestock numbers and the utilised agricultural area of these farms were higher than average. This, and the above-average percentage of farm managers who completed further training after their vocational education, points to a high degree of professionalisation, or to full-time farms. Six per cent of all farms belong to cluster 6.

Only three per cent of all farms belong to cluster 7. These farms perform significantly more contractor services for third parties, thereby achieving addition revenues of CHF 26,075 but on average also needing to invest another CHF 18,000 in machinery. As early as 2004, the 'Contractors' cluster showed a high use of on-farm family labour, as well as above-average revenue from contracting services. Thus, the agricultural related branch was not relaunched, but further expanded, whilst

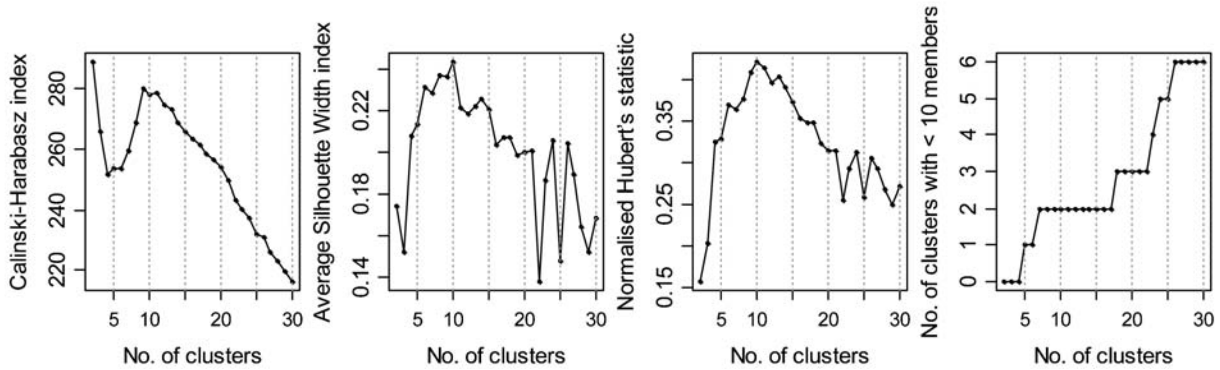

Figure 1: Results of the quantitative cluster validation. **Source**: Own calculations

Table 4: Results of the cluster bootstrapping

	Cluster							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Average overlap[1)]	0.80	0.90	0.77	0.68	0.65	0.74	0.82	0.54
	No. of repetitions with…							
Overlap >75%	79	96	67	41	22	53	73	47
Overlap <50%	0	0	2	16	13	4	2	40

[1)]Arithmetic mean of the Jaccard index for 100 repetitions.
Source: Own calculations.

the size of other branches was steadily increased. Unused capacity reserves, e.g. where the farms have limited growth opportunities, are thus turned to good account.

In Cluster 8, on the other hand, the agricultural related branch of contracting services is curtailed in favour of other branches. This cluster therefore unites the 'Contractor dropouts'. In 2004, the 'Contractor dropouts' cluster was characterised by comparatively high revenues from contracting, plenty of land, relatively high number of employees, and an above-average agricultural income. This indicates that at the start of the period under investigation, these farms were faced with an impending decision regarding growth. Utilisation of the available labour and machine capacity now takes place on their own farm.

Productivity and income comparison

On average, labour productivity across all 1912 Swiss farms rose by approx. 9% in 5 years (Table 6). The annual growth of 1.5% is rather low compared to the literature (for example 2.1% p.a. in Kansas from 1996 to 2005 [Mugera *et al.*, 2012] or 2.5% p.a. in the European Union from 1993 to 2007 [Ciaian *et al.*, 2010]).

With a 32% rise[15], the 'Outsourcing-focused' cluster 6 achieved the highest average labour productivity increase by a significant margin. The 'Contractors' and the 'Sideline entrants' (cluster 7 and 3) improved their labour productivity by an average of 15% due to increases in turnover in the agriculture related sector and reduction of labour input, respectively. Although the 'Stable' cluster 1 achieved a below-average growth in turnover, they did on the other hand employ fewer labour units. The labour productivity of this cluster grew by around 11% in 5 years. The 'Wage labour-focused' cluster only slightly improved its labour productivity (+4%), since significantly more labour units were employed to expand production. At around 4% and 5%, the increase in labour productivity of the 'Contractor dropouts' and the 'Sideline dropouts' (cluster 8 and 2) was likewise below average. Only the 'family labour-focused' cluster 4 did not manage to improve its labour productivity over the course of time, employing significantly more family labour units without increasing its turnover accordingly. The result was a decline in labour productivity of approx. 8%.

A measure of total factor productivity (TFP), the MI is increasing across all farms by an average of approx. 2%. Although some of the mean TFPs differ significantly from one another, the differences are not statistically significant because of the overlapping confidence intervals between the clusters[16].

If we compare the mean TFP in Table 6 with the mean income growth in Table 7, it becomes clear that high productivity increases do not, per se, mean high income increases. To give an example, the 'Outsourcing-focused' Cluster 6 boosted its productivity more than all

[15] Comparing the different clusters by mean values in the following lines it is important to keep in mind that the standard deviations within the clusters (Table 6) are quite large meaning that all clusters have members with declining (increasing) labour productivity although the cluster mean is positive (negative).

[16] In order to calculate the average MI of each cluster, the MI that were calculated within each individual strata were aggregated for the original overall sample and analysed in terms of their membership of a cluster. This procedure implicates that the average change in productivity in each cluster only reflects the average change of cluster members relative to their strata but not relative to the whole sample. According to Latruffe *et al.* (2012: 271) confidence intervals of clusters were estimated by calculating the arithmetic mean of the cluster members' confindence intervals. The MI and the confidence intervals (for 2000 repetitions) were calculated with the functions 'malmquist.components' and 'malmquist' in the FEAR package in R (WILSON, 2008).

Table 5: Results of the cluster analysis

		Cluster 1 Stable	Cluster 2 Sideline dropout	Cluster 3 Sideline-oriented	Cluster 4 Family labour-focused	Cluster 5 Wage labour-focused	Cluster 6 Outsourcing-focused	Cluster 7 Contractor	Cluster 8 Contractor dropout	All farms	
										Mean	Standard dev.
No. offarms	No.	1035	104	160	297	175	124	60	45	2000	2000
Distribution	%	52%	5%	8%	15%	9%	6%	3%	2%	100%	100%
Clustervariables (mean absolute deviation 2004–2009)											
Family-labour on farm	AWU	−0.03	0.20	−0.22	0.44	−0.37	−0.01	−0.08	0.10	0.01	0.32
Wage labour on farm	AWU	−0.03	−0.06	0.01	−0.19	0.67	−0.09	0.09	−0.07	0.01	0.37
Expenses for outsourced work	CHF	307	1748	491	46	810	13789	1354	816	1281	5229
Revenues for work on neighbouring farms	CHF	451	735	315	569	−152	490	26075	−20417	721	7018
Family-labour off farm	AWU	−0.01	−0.54	0.38	−0.03	−0.02	0.01	0.01	0.05	−0.01	0.21
Descriptive variables (mean absolute deviation 2004–2009)											
Livestock population	LU	1.6	3.5	1.4	2.6	3.8	7.6	1.9	4.5	2.5	8.6
	SG[3)]	cd	bod	d	bc	ab	a	abcd	abcd		
Area	UAA	0.3	1.3	−0.1	0.8	1.2	3.1	0.3	1.9	0.7	3.4
	SG[3)]	b	ab	b	b	ab	a	ab	ab		
Workload[4)]	AWU	0.05	0.17	−0.05	0.11	0.24	0.34	0.08	0.18	0.10	0.48
	SG[3)]	c	bc	d	b	ab	a	abcd	abcd		
Labour input[5)]	AWU	−0.06	0.14	−0.21	0.25	0.31	−0.06	−0.05	0.09	0.02	0.42
	SG[3)]	d	bc	e	a	ab	d	d	cd		
Labour balance[6)]	AWU	−0.11	−0.03	−0.16	0.14	0.07	−0.40	−0.13	−0.09	−0.08	0.57
	SG[3)]	b	bc	b	d	cd	a	abc	bc		
Structural features (mean 2004)											
Family-labour on farm	AWU	1.28	1.01	1.29	1.17	1.56	1.26	1.40	1.28	1.28	0.37
Wage labour on farm	AWU	0.29	0.44	0.28	0.46	0.37	0.62	0.42	0.52	0.36	0.48
Expenses for outsourced work	CHF	6857	8420	7260	7478	10511	10936	9302	14264	7875	8221
Revenues for work on neighbouring farms	CHF	3653	4358	2837	3486	5185	6392	12477	35113	4876	11297
Family-labour off farm	AWU	0.17	0.68	0.20	0.20	0.17	0.11	0.17	0.16	0.20	0.26
Livestock population	LU	25.25	23.5	25.2	26.7	30.3	34.9	25.5	32.2	26.6	15.8
Area	UAA	19.44	21.0	18.3	20.1	23.8	24.4	22.6	25.2	20.4	9.4
Open arable land	UAA	4.09	6.1	3.6	4.1	6.4	7.9	6.0	9.3	4.8	6.7

Source: wn calculations

Notes:

[1]. lds highlighted in grey: The mean of the cluster deviates more than **one** cluster standard deviation from the mean of all farms (positive/negative).

[2]. Underlined digits: The mean of the cluster deviates more than **one-half** cluster standard deviation from the mean of all farms (positive/negative).

[3)]. Significance group (SG). According to the pairwise Kruskal-Wallis test (1952), if two clusters do not have the same letters in their group name, there exists a significant difference between these clusters (P<0.05, P-value adjustment according to HOLM, 1979).

[4)]. The farm's total workload is arrived at by multiplying all farm production activities in 2004 and 2009 by their corresponding, yet constant-over-time, working-time requirement coefficients.

[5)]. Labour input for farm = family labour on farm + wage labour + labour share of contracting services on farm.

[6)]. Labour balance for farm = workload–labour input.

Table 6: Growth of turnover, labour input, labour productivity and total factor productivity from 2004 to 2009

	Δ Deflated Turnover [1000 CHF] M[1]	Δ Labour Input [AWU] M	Labour Productivity Change			Malmquist Index Total Factor Productivity Change			
						95% Confidence Interval			Interval Overlap
			M	SD[2]	SG[3]	Lower boundary	M[1]	Upper boundary	
All Farms	14.9	0.02	8.7%	36.7%		−3.0%	+1.8%	+6.5%	
Cluster 1	8.3	−0.06	10.6%	34.4%	b	−2.1%	+2.5%	+6.9%	a
Cluster 2	19.6	0.13	4.5%	30.9%	bc	−1.0%	+3.5%	+9.3%	a
Cluster 3	−2.1	−0.20	14.9%	40.9%	b	−6.0%	−1.1%	+3.8%	a
Cluster 4	11.8	0.25	−7.5%	31.1%	d	−7.5%	−3.2%	+1.7%	a
Cluster 5	33.2	0.30	4.3%	38.6%	cd	−1.0%	+3.7%	+8.4%	a
Cluster 6	60.7	−0.09	31.7%	47.3%	a	+1.1%	+6.7%	+11.6%	a
Cluster 7	23.8	0.02	15.3%	34.2%	b	−4.3%	+3.5%	+8.7%	a
Cluster 8	28.2	0.04	4.2%	35.2%	bcd	−4.6%	+0.8%	+7.4%	a

Source: Own calculations.
Notes:
1). M: Arithmetic mean.
2). SD: Standard deviation.
3). SG: Significance group. If two clusters do not have the same letter in their group name, according to a multiple Kruskal-Wallis test (Conover, 1999), a significant difference exists between these clusters ($P<0.05$, P-value adjustment according to Holm, 1979).

the others whilst experiencing an average change in income. The reason for this is that the use of the contractor results in additional third-party costs. By contrast, the 'Family labour-focused' Cluster 4 managed to keep its agricultural income despite declining productivity, since it was able to expand its employment of labour on the farm without incurring additional costs. In terms of the organisation of labour use, the only crucial factor for the farming household is ultimately how household income changes in relation to the family workforce deployed on- and off-farm. The 'Wage labour-focused' and the 'Contractor' clusters 5 and 7 contrast significantly positively with the 'Stable', 'Sideline-oriented' and 'Family labour-focused' clusters 1, 3 and 4, with the 'Contractor' cluster benefiting in particular from increases in turnover in an agricultural related market with relatively stable prices compared to the actual agricultural market.

5. Conclusions

This paper investigated the relationship between changes in labour use, farm size, farm income, and productivity. We approved the intuitive interdependencies between the different types of labour except for the off-farm contracting services that obviously do not contribute to the regulation of farm labour capacities. In general, higher labour productivity and TFP lead to higher family farm incomes (per on-farm family labour).

By means of a cluster analysis we identified 7 major strategies to adjust labour input. Between 2004 and 2009, just over half of the sample–the cluster of the 'Stable' farms–kept their inputs constant, and did not achieve the worst operating results by doing so. A further eight per cent of the farms–the sideline-oriented ones–decided to embark on a process of contraction of the farm in favour of stronger off-farm commitments.

Table 7: Average growth in agricultural income [AI] and household income [HI]

	Income in 2004 [1000 CHF]				Nominal mean absolute change 2004–2009 [1000 CHF]							
	AI	HI	AI per FAWU[1]	HI per FAWU[2]	AI	SG[3]	HI	SG	AI per FAWU[1]	SG	HI per FAWU[2]	SG
All Farms	66.6	85.5	54.9	61.3	−3.2		1.7		−4.1		0.8	
Cluster 1	65.1	83.2	52.7	60.1	−3.2	a	0	bcd	−2.1	ab	1.3	b
Cluster 2	59.3	91.7	59.3	56.8	3.3	a	−8.6	d	−9.3	bc	11.3	ab
Cluster 3	58.1	80.9	50.4	58.6	−11.3	b	12.4	a	−5.3	b	−0.8	b
Cluster 4	62.9	82.4	57.5	64.1	0.1	a	2.5	abc	−16.7	c	−13.8	c
Cluster 5	74.9	93.4	51.3	58.5	−10.7	b	−4.7	cd	2.6	ab	11.1	a
Cluster 6	84.9	95.9	68.8	71.7	−1.4	a	7.4	abc	−0.3	ab	6	ab
Cluster 7	73.9	89.3	56.2	61.4	11.9	a	18.4	ab	12.5	a	15.2	a
Cluster 8	81.3	97.5	67.3	72.2	−3.9	ab	6.6	abcd	−8.9	bc	−3.4	abc

Source: Own calculations
Notes:
1). FAWU: Family annual working units, farm
2). FAWU: Family annual working units, farm and sideline
3). SG: Significance group. If two clusters do not have the same letter in their group name, according to a multiple Kruskal-Wallis test (Conover, 1999), a significant difference exists between these clusters ($P<0.05$, P-value adjustment according to Holm, 1979).

Likewise interesting is the heterogeneity of the 40 per cent of farms in the sample under consideration that are growing. The six different patterns indicate that simple categorisations of the three types of labour–family and wage labour as well as contracting services–evidently fall short of the mark, and that differentiated theories on their use must be developed. This, for example, holds true for the phenomenon of one cluster substituting work on their own farm for contracting services on neighbouring farms, whilst a similarly-sized cluster decides on the reverse substitution process. The fact that these two clusters (7 and 8) from the outset exhibit high expenditure for contracting services points to the great importance of the concept of path dependencies in such a theoretical approach. Moreover, the fact that, as part of the growth process, both clusters virtually change places on the income ladder, indicates that purely economic explanatory approaches fall short of the mark here, and that social factors will also be playing an important role.

Since forecasts for the agricultural sector are also increasingly based on the simulation of individual farms (Kleinhanss *et al.*, 2002; Möhring *et al.*, 2011), it makes sense to integrate the existence of the different growth patterns in the modelling of growth processes too. A challenge faced here is to link the structural features of the modelled farms with the allocation of specific types of growth. Further empirical analyses of growth processes in different historical and socioeconomic contexts will help us cope with this challenge as realistically as possible.

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Using a farm micro-simulation model to evaluate the impact of the nitrogen reduction mitigation measures on farm income in Ireland

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ABSTRACT
The introduction of the Water Framework Directive in 2000 (European Parliament and Council 2000) has incentivised policy-makers to bring the quality of all water streams in EU member states up to a 'good ecological status' by 2015. Although a lot of work has been carried out since the introduction of the Directive, it is also evident that progress in improving water quality has been very slow. The main reason for such slow progress is the lack of robust evidence about the sources of pollution and the effects of possible mitigation measures. Also, there is insufficient knowledge regarding the economic implications of the various mitigation options. In this paper we introduce a microsimulation model that can help policymakers to evaluate the economic impact of Nitrogen (N) mitigation measures. In this initial case study, two measures are considered: 1) a stocking rate reduction to achieve a maximum level of organic nitrogen of 170 kg/ha; 2) a 20 percent stocking rate reduction. The results of this study confirm the hypothesis that introduction of these measures would lead to reduction in farm gross margins, which is consistent with the previous research in Ireland and UK.

KEYWORDS: Water Framework Directive; Nitrates Directive; microsimulation; policy evaluation; water quality; environmental policy

1. Introduction

Nutrient enrichment of water streams has been identified as an important environmental problem (Novotny, 2003, Johnson *et al.*, 2010). The main impact of excess nutrients in water bodies is eutrophication, causing an increase in biological and chemical oxygen demand, an unpleasant odour from the water, a loss of habitats, changes to the river bed that affect ship/boat navigation as well as negatively impacting on recreational usage. Thus, there are significant socio-economic effects associated with nutrient enrichment in addition to the environmental effects. These considerations led to the introduction of legislation that aims to restrict pollution of water bodies and to protect their habitats (Habitat Directive (Council of the European Union 1992)), Freshwater Fish Directive (Council of the European Union 1978), Birds Directive (Council of the European Union 1979)); to protect the uses of the streams (Drinking Water Directive (Council of the European Union 1980), Bathing Water Directive (Council of the European Union 1976), Sewage Sludge Directive (Council of the European Union 1986), Urban Waste Water Treatment Directive (Council of the European Union 1991a)); and to restrict nitrogen and other pollutants' loss to overland/ground waters (Nitrates Directive (Council of the European Union 1991b)) amongst others. Perhaps the most comprehensive legislative document to date is the Water Framework Directive (WFD), which not only protects water resources from deterioration but also demands improvement in water quality to 'good ecological status' by 2015 (European Parliament and Council 2000).

The complexity of environmental interactions poses a problem for researchers in identifying the sources of pollution and establishing robust causal relationships between different human activities and the volume of pollutants in streams. Lally *et al.* (2009) state that emissions of organic and inorganic nitrogen cannot be observed at a reasonable cost. O'Donoghue *et al.* (2010) studied the statistical relationship between water quality at over 3,000 monitoring sites in Ireland and human activities in the upstream areas and found that there was a significant statistical relationship between agricultural activities (in addition to other activities) and lower water quality in the downstream areas. This is in line with the findings of the Department of Environment, Community and Local Government (DEHLG) (2010),

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which states that intensively farmed agricultural land may be a source of excess nutrients in Irish waters. There are a large number of pollutants from agriculture that may present a potential problem to the wider environment and to water resources in particular, however the main pressure to water quality comes from nutrient enrichment (Schulte *et al.*, 2006; Doole, 2012, 2013).

Nitrogen (N) is an important nutrient and is essential to the production and growth of all organisms. The present structure and high output levels of agriculture could not be maintained without the widespread use of synthetic and organic fertilisers (Merrington *et al.*, 2002). However, in excess, N becomes a pollutant (Doole, 2012). There is some evidence, that despite the efforts of Irish farmers to reduce N loss from their land, the production processes used and the prevailing weather conditions still lead to the loss of nutrients to the wider environment (Donohue *et al.*, 2006; John, 2008). However recent evidence has shown that there have been improvements over time, possibly as a result of Agri-Environmental measures and improved nutrient management on farms (O'Donoghue *et al.*, 2014).

A large volume of literature discusses the diffuse pollution from agricultural land (Ritter, 2001; Merrington *et al.*, 2002; Novotny, 2003; Donohue *et al.*, 2005; Donohue *et al.*, 2006; O'Donoghue *et al.*, 2010). The Environmental Protection Agency (EPA) in Ireland reports that in 2008 out of 180 river sites of Nitrogen monitoring five sites had the highest values; 7 percent of groundwater monitoring sites failed to comply with the Irish Threshold Value concentration in the same year and 1 percent failed to comply with the Drinking Water maximum allowable concentrations, which is related to areas with more intensive agricultural practices (John, 2008).

The primary factors that encourage N leaching from Agriculture are over-fertilisation, excessive livestock numbers, improper use of manure, and exposure of bare soil during drainage periods (Fezzi *et al.*, 2008; Bateman *et al.*, 2007). Measures that aim to reduce N leaching should thus be targeted at these factors. The appropriate choice of mitigation strategies is connected to the N cycle in the agricultural environment as these strategies would aim to impact particular stages of the N cycle. There are three main pathways through which different forms of N and its compounds circulate in the agricultural environment: inputs (into the soil), transformations (within the soil), and losses (out of the soil) (Merrington *et al.*, 2002). Mitigation strategies aim at controlling these pathways through either restricting excessive N input use or reducing N losses to the environment that are already in the system. Due to the weather and other environmental variations it is easier to target the reduction of N inputs to the ecological system as less N is introduced into the environment, less can potentially be lost through undesirable pathways (Ritter, 2001; Merrington *et al.*, 2002; Novotny, 2003). The input of N into agricultural system comes from chemical fertiliser application, animal manure and crop residue (IFA, 2007). A number of mitigation options are available to decision-makers to address N loss from agriculture.[4]

[4] The full discussion is beyond the scope of this paper. The interested reader is referred to Cuttle *et al.*, 2006; Novotny, 2003; Merrington *et al.*, 2002 and Ritter, 2001 for a more comprehensive treatment of mitigation startegies.

In this paper, within a microsimulation framework, the potential impact of two N pollution reduction measures on farm income for dairy farms in Ireland is estimated. The two considered mitigation measures have previously been assessed by Hennessy *et al.* (2005) and Fezzi *et al.* (2008) are considered, and are 1) a stocking rate reduction to achieve a maximum organic N of 170 kg per hectare; 2) a 20 percent livestock units reduction.

A dairy cow produces 5.3 m^3 of slurry in 16 weeks of housing (S.I. 610 of 2010), which contains approximately 19 kg of N. This manure/slurry has to be spread overland or exported from the farm. Livestock also deposits manure/urea directly on fields during grazing periods. In Ireland the Good Agricultural Practice regulations (S.I. 610 of 2010) place a restriction on the amount of manure and inorganic fertilizer that may be applied per hectare - presently the amount is capped at 170 kg of N per hectare, with a possibility to derogate to 250 kg of N per hectare. This is the basis for our first scenario. It has been suggested in the literature that in order to achieve the objectives of WFD, the introduction of changes such as a 50 percent reduction in the application of fertilisers to crops and grass, sheep stocking rates to be halved and a reduction in cattle stocking rates of 20–25 percent may be needed (Haygarth *et al.*, 2003; Bateman *et al.*, 2006). For dairy farms the latter requirement is likely to be most pertinent so we consider a 20 percent reduction in livestock units.

Some work has explored the costs of mitigation measures: Cuttle *et al.* (2006), Hennessy *et al.* (2005) and Lally *et al.* (2009) used linear programming in their estimations, while Fezzi *et al.* (2008) used a farm accounting approach to find the possible cost of the mitigation measures. This paper contributes to this nascent literature by introducing a model that allows the simulation of impacts associated with policy responses such as a change in N production, and resultant changes in farm income, at the farm level.

The rest of the paper is structured as follows: the data set that is used for the estimations is discussed along with summary statistics in section 2. The methodology is explained in section 3. The results are presented in section 4 and conclusions are drawn in section 5.

2. Methodology

Estimation of N produced on the farm

In this paper we developed a model that can allow us to readily assess the impact of N reduction measures on farm N budgets and on farm incomes within the context of implementation of the Water Framework Directive. In doing so it is first necessary to decide how to estimate the farm's N budget. Often researchers focus on modelling the run-off and undesirable losses of N from farm land. This approach leads to difficulties for modellers as it requires the development of a separate hydro-geological model that would allow the prediction of N losses through different pathways. This would require a lot of hydro-geo-ecological data in very high resolution. Such data seldom exists nationally. As an alternative approach, we approximate N losses using a 'reduce inputs' approach. The assumption behind this approach is that if less N is introduced into the environment during the production process on the farm, then less is subsequently lost through undesirable pathways – via volatilisation, run-off, and /or leaching. A proportional reduction is assumed throughout.

The total N on a farm depends on the number of livestock units (LU)[5] (organic N) and on the amount of chemical fertiliser used as a part of the production process (chemical N). Haygarth *et al.* (1998) and Merrington *et al.* (2002) report that 70–80 percent of N ingested by the animals during grazing and/or feeding on concentrates is subsequently excreted in manure. The level of organic N used in enterprise *j* is calculated by multiplying the number of LU of type *k* in that enterprise of the farm (NLU_{kj}) by the annual N excretion rate of that LU type (E_k) and summing across the *K* types of LU. This is then added to the Inorganic N for enterprise j and summed over the *J* enterprises to obtain the total N on the farm, as is given by:

$$N_i = \sum_{j}^{J} \left(\sum_{k}^{K} \left(E_k NLU_{kj} \right) + Inorganic\ N_j \right) \quad (1)$$

We used the 'annual nutrient excretion rates (E_k) for livestock' tables as published in Good Agricultural Practice for Protection of Waters (European Communities 2010) to determine the N produced by each animal on the farm −85 kg of N per dairy LU, 65 kg of N per beef LU and 7 kg of N per sheep LU[6]. The number of kg of chemical fertiliser purchased by the farmers was used to determine the amount of chemical fertiliser used on the farms.

Estimation of the farm profit

Econometric techniques were utilised for determining the output and cost functions. Animal numbers and chemical fertiliser each affect the output volume (Y) and the costs (C) on the farms (equations 2 and 3). Farms in Ireland usually engage in more than one enterprise. Each enterprise is modelled separately here due to the fact that only dairy farms are considered. However, when the farm system is not important adopting a 'whole farm' approach may yield better estimates. X_{ij} is a vector of explanatory variables, where i denotes individual farm and j denotes each farm enterprise (dairy, beef or sheep), and variables include the size of farm, the volume of fertiliser and concentrated used, number of livestock units, forage area, etc. (see Table 2 and Table 3 for a full list of variables used in the model for each function estimation). These variables determine the level of Y_{ij} and C_{ij} in equations 2 and 3. When more LU are on the farm, more output is produced, however more organic N is also produced on the farm and costs incurred by a farmer to feed and maintain animals are also greater.

$$Y_{ij} = (X_{ij} \,|\, \beta_j, \varepsilon_{ij}^{y}) \quad (2)$$

$$C_{ij} = (X_{ij} \,|\, \gamma_j, \varepsilon_{ij}^{c}) \quad (3)$$

Thus through manipulating (reducing) the number of animals and the amount of chemical fertiliser used, farmers could reduce the N budget on the farm and hence reduce environmental pressures. A positive relationship is assumed between animal numbers, the amount of fertiliser and the value of gross output and costs.

There are a variety of functional forms one could use when estimating output or costs and since the true functional form cannot be known, the problem is to choose the form that best suits the task at hand (Griffin *et al.*, 1987). The most commonly used functional form is the log-log, Cobb-Douglas and trans-log. However, recently Flichman (2011) discussed the use of functional forms in bio-economic models and criticised the Cobb-Douglas functional form as inferior to trans-log functions. However, in our model using a trans-log specification would lead to a loss of degrees of freedom. Production and cost functions are estimated using log-polynomial ordinary least squares (OLS) regressions. A similar parametric approach was used by Fezzi *et al.* (2010) who used linear regression models to estimate the change in farm gross margin that arises from different policy measures. Their approach allowed avoiding model complication by estimating only one function. In contrast to Fezzi et al (2010), we estimate separate equations for gross output and direct costs and then calculate gross margin. This allows the impact of shocks on these components to be explored and the simulation of changes in these components at a farm system level and thus maybe more useful for modelling purposes. Three production and three cost functions are estimated in our model: dairy gross output, dairy direct costs, cattle gross output, cattle direct costs, sheep gross output, and sheep direct costs (equations 2 and 3). The level of farm gross output and direct costs determine a farm's profit (equation 4):

$$\pi_i = Y_i - C_i - FC_i \quad (4)$$

Farm profit π_i is calculated as the farm's gross output (Y_i) less farm's direct costs (C_i) and fixed costs (FC_i).

Developing a micro-simulation model

The model (as described in equations 1–4) allows the simulation of changes in farm profits due to output or cost changes at an enterprise level. The impact of different measures to reduce N can differ in both the economic and in the environmental dimensions across farms, thus the analysis should be carried out at a farm level. Microsimulation techniques allow us to conduct analyses at this scale. Microsimulation techniques have been widely used for many years and are an effective tool for evaluating the socio-economic impacts of different mitigation options where it is difficult or impossible to conduct a real life experiment (Merz, 1993; O'Donoghue, 2013). The microsimulation

[5] In NFS a dairy cow is taken as the basic grazing livestock unit. All other grazing stock is given equivalents as follows: Dairy cows 1.0; Suckling cows 0.9; Heifers-in-calf 0.7; Calves under 6 mths. 0.2; Calves 6-12 months 0.4 Cattle 1-2 years 0.7 Cattle over 2 years 1.0 Stock bulls 1.0; Ewes and rams 0.20 (lowland) 0.14 (hill); Lambs to weaning 0.00 (lowland), 0.00 (hill); Lambs after weaning 0.12 (lowland), 0.10 (hill); Hoggets and wethers 0.15 (lowland), 0.10 (hill). For more details see Connolly *et al.* (2008).

[6] A N excretion rate of 7kg per sheep livestock unit is used in this paper, despite the fact that for lowland sheep the N excretion rate is 13kg (European Communities, 2006). However, this excretion rate covers both the ewe and its lambs and would thus result in an over-estimate of N/ha on the farms and hence subsequently produce a lower cost per unit of N abated in the second scenario.

approach is widely used for income generation modelling, tax system evaluation and pension schemes evaluation *inter alia* (Mitten *et al.* 2000; Sparado 2007; O'Donoghue, 2013). Microsimulation can be carried out using various techniques, for example, linear programming (Hennessy *et al*, 2005), partial budgeting (Fezzi *et al.*, 2008) or econometric regression analysis (Fezzi *et al.*, 2010).

All of these techniques allow for the modelling of changes at the farm level. The choice of a particular technique depends on the objective of the model. Hennessy *et al.* (2005) utilise the FAPRI-Ireland Farm Level Model, which is a dynamic gross margin maximizing model and was first described by Breen and Hennessy (2003). The linear programming approach allows model optimization, however in our model we are not trying to optimize farm production but rather to understand how the farm system affects the costs of the mitigation measures. In the Fezzi *et al.* (2008) farm budget model the underlying assumption in the 20 percent LU reduction scenario is that the output and costs would be reduced by 20 percent as well. However, this assumption may not hold in reality as the relationships and dependencies between variables are more complex. In this work we follow Fezzi *et al.* (2010) in adopting a regression framework. Regression analysis was chosen for our model as the most appropriate technique for our estimations as it allows us to capture the marginal effect of changes in the variables of interest, e.g. the change in the number of livestock units.

The schematic of the overall simulation procedure is depicted in Figure 1. The model input is the farm level data which is described in the next section of this paper. The scenarios considered in the model are the two mitigation options to reduce N on the farms. These measures would lead to changes in the farm inputs and/or outputs through reductions in the dry stock, fertiliser usage, feed change etc.

The impact of the alternative mitigation measures on individual farm profit (π_i) is simulated using estimates of output and cost functions based on farm-level data (equations 2 and 3). The fixed costs are not affected by the scenarios in the simulations, thus, the changes in the farm profit are due to changes in farm gross margin (GM) (equation 5).

$$GM_i = Y_i - C_i \tag{5}$$

$$Y_{ij}^{\circ} = (X_{ij}^{\circ} | \beta_j, \varepsilon_{ij}^{y}) \tag{6}$$

$$C_{ij}^{\circ} = (X_{ij}^{\circ} | \gamma_j, \varepsilon_{ij}^{c}) \tag{7}$$

$$\pi_{ij}^{\circ} = \sum Y_{ij}^{\circ} - \sum C_{ij}^{\circ} \tag{8}$$

$$\Delta\pi_i = \pi_i^{\circ} - \pi_i \tag{9}$$

The simulations are carried out by holding the regression coefficients (β_j, γ_j) and the error terms (ε_{ij}^{y}, ε_{ij}^{c}) constant and changing the explanatory variables (X_{ij}^{o}) according to the scenarios (in our case study scenarios it is the number of LU that is altered). When the parameters of the model are estimated the new levels of production and cost are predicted for each enterprise (denoted as C_{ij}^{o}, Y_{ij}^{o} in equations 6 and 7). The results are then aggregated to the farm level (equation 8). The impact of the simulated changes in the animal numbers and/or fertiliser is the difference between farm profit before (π) and after the change (π°) (equation 9).

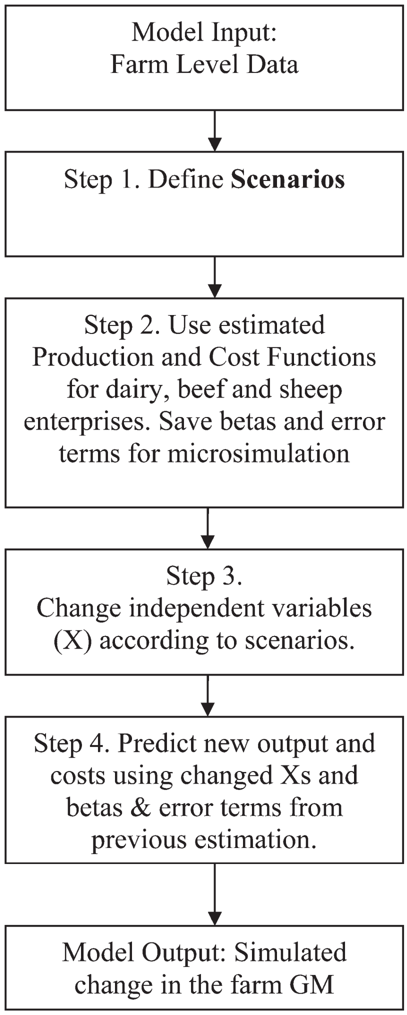

Figure 1: Simulation Model Flow Diagram

$$N_i^{\circ} = \sum_{j}^{J} \Big(\sum_{k}^{K} \left(E_k NLU_{kj}^{\circ} \right) + Inorganic\ N_j \Big) \tag{10}$$

The changes in N come from the change in animal numbers according to the particular scenario. In this case study we explored two scenarios: 1) a stocking rate reduction to achieve maximum organic N of 170 kg per hectare; 2) a 20 percent LU reduction. In the first scenario farmers are assumed to reduce livestock units starting with the enterprise that has the lowest gross margin per LU to reach 170 kg of N per hectare. The adjusted number of livestock units is NLU_{kj}° (equation 10), where k is a type of a LU – dairy, beef or sheep. The underlying assumptions about the way farmers would drop LU are different in each scenario. In the first scenario it is assumed that farmers would drop the LU with the lowest GM per animal. In the second scenario the assumption is that farmers would reduce all types of LU proportionally by 20% if required to do so.

$$NLU_{ki}^{\circ} = (0.8 \times NLU_{ki}) \tag{11}$$

In the second scenario the number of LU on each farm is reduced by 20 percent for each enterprise (equation 11) and the new N° on the farm is calculated as in equation 10.

The final change in N on the farm is the difference between the N level before the simulations and the level, N^{o}, that is simulated for the farm after the mitigation measure introduction (equation 12).

$$\Delta N_i = N_i^{\circ} - N_i \tag{12}$$

$$Av.C = \frac{\Delta \pi_i}{\Delta N_i} \tag{13}$$

Thus, this methodology allows us both to simulate the changes in farm profit and to simulate the change in N on the farm as a result of the mitigation measures. It can potentially be used by decision-makers in determining not only the level of abatement that can be achieved through different measures and the cost associated with them but also to compare the average cost of abatement (Av.C) for each individual farm (equation 13).

3. Data

In order to simulate the changes at a farm-level, socio-economic data at the farm level is required. Teagasc - The Irish Agriculture and Food Development Authority- has conducted the National Farm Survey (NFS) on an annual basis since 1972 (Connolly *et al.*, 2010). The resultant dataset contains information for a sample of approximately 1,200 farms per annum that are nationally representative of over 100,000 farms in Ireland. This sample, however, excludes pigs and poultry farms due to an inability to obtain a representative sample for these types of farms. It is also not representative of very small farms. The NFS dataset contains socio-economic information which allows analysis of the physical and economic performance of the different farming sectors in the Republic of Ireland.

In this paper NFS data for the year 2008 is used as in later years there was high volatility in farm outputs/inputs, making the estimations potentially less reliable. Farms in the NFS are assigned to one of six possible systems: specialist dairy; dairying other; cattle rearing; cattle other; mainly sheep; mainly tillage (Hennessy *et al.*, 2011). The category assignment is based on the dominant enterprise, which is established based on the Standard Gross Margins (SGMs) under the EU FADN typology set out in the Commission Decision 78/463 (Hynes *et al.*, 2008). Under this methodology SGM is assigned to each type of farm animal and each hectare of crop. Farms are then classified into groups called particular types and principal types, on the basis of the proportion of the total SGM of the farm which comes from the main enterprises (after which systems are named). This methodology was adapted to suit Irish conditions more closely (the reader is referred to Connolly *et al.*, 2008 for further details). Farms in Ireland typically engage in more than one enterprise. For the purpose of our research we are focussing on farms that are identified in the NFS as 'specialist dairy' (from now on referred to as dairy) and 'dairy and other activities' (from now on referred to as dairy other).

The number of farms in the NFS sample varies from year to year from 1,279 farms in 1994 to 1,102 in 2008, which reflects the decreasing number of farms in Ireland, however the farms are getting bigger in size and more specialised. National weights are applied to represent the population of farms in Ireland. National weights are produced by Teagasc on the basis of the Census of Agriculture tables produced by the Irish Central Statistics Office (CSO). All summary statistics and model results reported in this paper are produced on the basis of weighted NFS data.

There are two primary reasons for focusing on dairy farms in this research:

- the relatively good economic performance of dairy farms in Ireland and
- environmental pressures generally associated with intensive dairy farm systems.

In terms of economic significance, dairy farms in Ireland have gross margins that are high relative to other farm systems and dairy farms' gross margins are growing at a faster rate. Gross Margin (GM) is a good indicator of farm performance because it represents the difference between Gross Output (GO) and Direct Costs (DC). Furthermore, movements in GO (Figure 2) and DC (Figure 3) provide useful information about the source of changes in GM (Figure 4).

It can be seen in Figure 4 that dairy and dairy other farms have significantly higher GM than cattle, cattle rearing and mainly sheep systems. It is also evident that dairy GM is growing at a rate higher than in other systems during the period. This is due to the high growth rate of dairy output (Figure 2) despite the fact that for the dairy farms the value of direct costs was growing at the same time (Figure 3). The rapid growth in dairy farms' GO was caused by both increased milk yield per animal and due to consolidation in the industry with fewer farms producing more milk.

Dairy and dairy other farms are not only leaders in terms of economic performance; they also have higher organic N production and chemical N use per hectare (Table 1) relative to other systems. The national average (which is lower than the non-derogation requirement of 170 kg N per hectare under SI 610/2010 (European Communities 2010)) disguises the range of organic N application across Irish farms with 27 percent of the farms in Ireland producing more than 170 kg of organic N per hectare. At the moment farmers that are over the requirement of 170 kg of organic N per hectare can apply for derogation, but the regulation may become more stringent in the future.

The dairy system turns out almost twice as much organic and chemical N per hectare as any other system. Dairy other farms, despite reducing N emissions over the previous few years, still turn out higher amounts than in other systems. Twenty one percent of the dairy farms and four percent of dairy other farms in Ireland in 2008 exceeded the limit of 170 kg N per hectare (Table 1). Additionally, 3 percent of dairy farms were found to have exceeded chemical N limit per hectare.

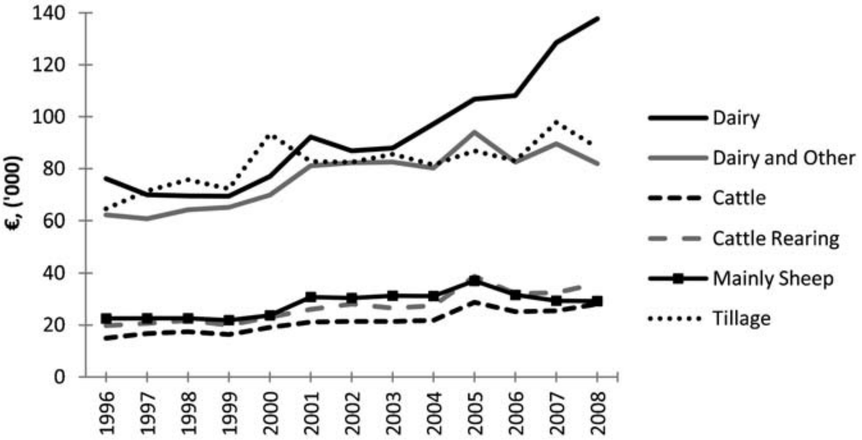

Figure 2: Dynamics of Gross Output on farms in Ireland (1996–2008)

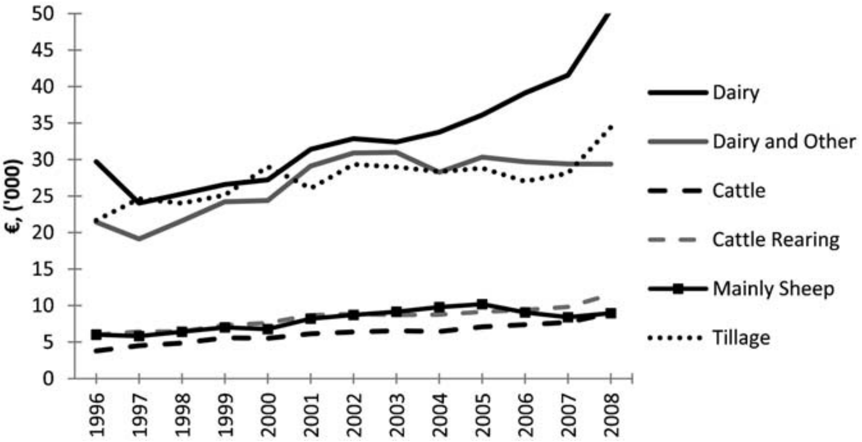

Figure 3: Dynamics of Direct Costs on farms in Ireland (1996–2008)

4. Results

Model Estimates

The production and cost functions were estimated for each enterprise on the farm using log-polynomial ordinary least squares (OLS) regressions. All of the explanatory variables used in the estimations are enterprise-specific, with the exception of farm size. All results are based on NFS data weighted to represent dairy farms nationally.

The estimated production functions for dairy, beef and sheep enterprises are reported in Table 2 and estimates of the cost functions for dairy, beef and sheep enterprises are reported in Table 3. The significance levels of the estimates and the standards error are also reported. Concentrates and fertiliser usage are the main drivers of both production and costs on dairy farms, which are grass-based in Ireland. Both variables are driving the output and the costs up with the effect of fertiliser usage less profound for costs on the dairy farms in Ireland. Farm size and number of livestock units are included in the model to capture economies of scale. The number of dairy livestock units on dairy farms drives output per LU up and the negative coefficient the square term shows the diminution return to scale. At the same time the costs per LU are falling indicating cost savings per LU for larger farms. Size of farm variable estimate is positive, but insignificant. Other costs mainly relate to enterprise specific expenses such as routine veterinary checks/treatments and expenses on artificial insemination. These expenditures are necessary for farms' operations and are driving an output up, however, they also present a considerable cost on the dairy farms in Ireland.

Gross margin analysis of policy scenarios

The analysis is focused on the farm GM because it changes in the short run while fixed costs are only adjusted in the long term. Table 4 presents the farm GM and the enterprise specific GM, GO and DC (with a prefix D representing dairy, C for cattle and S for sheep enterprises) that are anticipated to result under each mitigation scenario. Baseline figures, which reflect the average farm gross margins on the affected farms before simulations, are presented in parentheses. The simulated outcomes suggest that farm gross margin would decline significantly following a reduction of LU by 20 percent, decreasing from €63,779 down to €50,675 – a loss of an average €13,104 per farm[7]. Gross margins decline on average across all enterprises. Fezzi *et al.* (2008), using a farm budgeting model, which is based on similar UK

[7] In late May 2014, €1 was approximately equivalent to £0.81 and $1.37 (www.xe.com)

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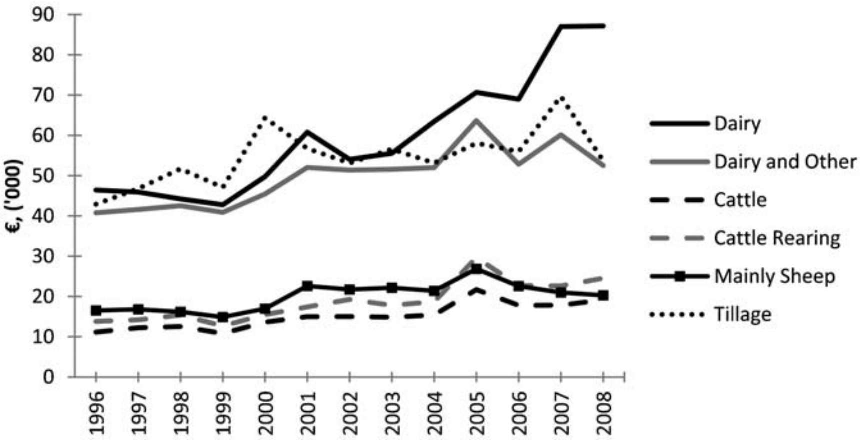

Figure 4: Dynamics of Gross Margin on farms in Ireland (1996–2008)

farm data, reports an average loss of £7,011 due to this measure, which is broadly consistent with our findings.

When the mitigation approach is instead to reduce organic N on the farm to a maximum of 170 kg org. N per hectare, the GM on the affected farms would decline on average by €4,237, or by €113 per hectare. This measure is more likely to affect farms engaged in relatively intensive production with stocking rates close to or over 2 LU per hectare and an average farm GM higher too (Table 4). This measure affects mostly beef gross output (CGO) and direct costs (CDC) which fall on average by €12,762 and €9,444 respectively leading to a loss in beef GM of €3,318 on average for the dairy and dairy other farms. The underlying assumption here is that the farmers drop the livestock with the lowest GM per animal. Results from the NFS sample in 2008 indicate that beef LU attract on average low GM returns on dairy and dairy other farms in Ireland and hence this enterprise is most affected.

The percentage change in GM, GO and DC as a result of the simulated policy scenarios is reported in Table 5. Reducing LU to achieve 170 kg organic N per hectare yields a decrease in farm GM of 5.21 percent-mostly due to fall in GM from the beef and dairy enterprises (Table 5). This is despite an associated fall in costs. The results also revealed that not all farms that exceed the 170 kg of organic N per hectare threshold are equally affected. Twenty five percent of dairy and dairy other farms exceed the limit in 2008 based on the weighted NFS data. If these farms were to reduce their emissions to comply with the stated limit, approximately 90.5 percent of these farms would have a reduction in GM and 9.5 percent would have a gain in GM due to the fact that on some farms the GM from beef cattle is zero or even negative.

Hennessy *et al.* (2005), using NFS data for 2002, found that 22 percent of dairy farms that exceed the limit would be negatively affected by this measure, with 10 percent of farms losing less that 10 percent of farm GM, 8 percent losing 10–20 percent of the farm GM and 5 percent losing more than 30 percent of farm GM. The rest of the farms would either be unaffected or benefit from this measure according to their study. In our study on the 2008 NFS data, 8.9 percent of affected farms would lose over 30 percent of their farm GM; 7.6 percent would lose between 20 to 30 percent of their farm GM and 58 percent of affected farms would lose between 10 and 20 percent of their farm GM.

If the farmers in Ireland were to reduce their livestock units by 20 percent, their GM per hectare would on average decrease by 21 percent. This measure would negatively affect all farm enterprises (dairy, cattle and sheep) on dairy farms and would lead to falls in DGM, CGM and SGM of approximately 20 percent, 24 percent and 38 percent respectively across these enterprises. These measure would not only lead to a loss of output squeezing already narrow farm margins, but would also be inconsistent with the Food Harvest 2020 agenda, an Irish policy, which requires the growth of agricultural output by about 33 percent (Food Harvest 2020).

Farm nitrogen implications under each mitigation scenario

The potential N reduction that would result from the mitigation measures would have important environmental

Table 1: Mean N per hectare and percentage of farms in N categories, 2008

	Org. N (kg per hectare)			Chemical. N (kg per hectare)			
Farm System	<170	>170	Mean	<226	226–279	>279	Mean
Dairy	79%	21%	142	92%	5%	3%	134
Dairy other	96%	4%	82	99%	1%	0	67
Cattle	99%	1%	72	100%	0	0	40
Cattle rearing	99%	1%	79	100%	0	0	42
Sheep	100%	0	36	100%	0	0	36
Tillage	100%	0	22	78%	1%	21%	62

Table 2: Results for dairy farms production function estimations

Dairy Enterprise		Beef Enterprise		Sheep Enterprise	
Ln(GO/LU)	**β**	**Ln(GO/LU)**	**β**	**Ln(GO/LU)**	**β**
Winter forage/LU	−0.0005** (0.0003)	Number of LU	−0.0041*** (0.0015)	Number of LU	−0.0042 (0.0235)
Other costs/LU	0.0011*** (0.0003)	Fertilizer/LU(€)	.0010*** (0.0006)	Forage Area	0.0223 (0.0169)
(Other costs/LU)^2	-1.37×10^{-7}** (3.5×10^{-5})	Concentrates/LU	0.0012** (0.0005)	Size of farm	−0.0211 (0.0217)
Concentrates/LU	0.0004*** (0.0001)	Other costs/LU	$-1.34\times10-7$ $(9.31\times10-7)$	Size of farm^2	0.00003 (0.0001)
Number of LU	0.0001 (0.0015)	(Other costs/LU)^2	4.00×10^{-7} $(1.\ 12\ \times10-7)$	Fertilizer (kg)	−0.00004 (0.0004)
(Number of LU)^2	-7.24×10^{-6}** (7.07×10^{-6})	Forage area	0.0023 (0.0019)	Fertilizer (kg)^2	$1.94\times10-8$ $(4.90\times10-8)$
Size of farm	0.0004 (0.0011)	Forage area^2	9.13×10^{-6} (0.00001)	Constant	5.834*** (0.61784)
(Size of farm)^2	2.94×10^{-6} (5.09×10^{-6})	Size of farm^2	-6.04×10^{-6} (9.00×10^{-6})		
Fertilizer	0.00005*** (8.47×10^{-6})	Fertilizer (kg)	0.00003 (0.00002)		
Fertilizer^2	-1.24×10^{-9}** (2.98×10^{-10})	Fertilizer (kg)^2	-4.06×10^{-10} (5.58×10^{-10})		
Constant	6.8384*** (0.0674)	Constant	6.0821*** (0.1000)		

Note: *** significant at 1% level; ** significant at 5% level; *significant at 10% level.

Table 3: Results for Dairy Farms Cost Function Estimations

Dairy Enterprise		Beef Enterprise		Sheep Enterprise	
Ln(DC/LU)	**β**	**Ln(DC/LU)**	**β**	**Ln(DC/LU)**	**β**
Winter forage/LU	0.0002*** (0.00009)	Number of LU	−0.0034*** (0.0004)	Number of LU	−0.0280** (0.0129)
Other DC/LU	0.0021*** (0.0001)	Concentrates/LU	0.0030*** (0.0001)	Concentrates	0.0002*** (0.00004)
(Other DC/LU)^2	-1.08×10^{-6}*** $(1.1\ 6\times10^{-7})$	(Concentrates/LU)^2	-2.38×10^{-6}** (2.48×10^{-7})	Winter forage	0.0002 (0.0004)
Concentrates/LU	0.0025*** (0.00008)	Other DC/LU	0.0025** (0.00009)	Size of farm	−0.0048 (0.0082)
(Concentrates/LU)^2	-1.47×10^{-6}*** (1.17×10^{-7})	(Other DC/LU)^2	$-8.1\ 9\times10^{-7}$ (7.07×10^{-8})	Size of farm^2	0.00003 (0.00006)
Number of LU	−0.0046 (0.0005)	Forage area	−0.0010 (0.0005)	Fertilizer (kg)	0.0006** (0.0002)
(Number of LU)^2	0.00001 (2.31×10^{-6})	Forage area^2	-1.52×10^{-6}*** (3.39×10^{-6})	Fertilizer (kg)^2	-8.39×10^{-8}*** (2.56×10^{-8})
Size of farm	0.0005 (0.0004)	Size of farm^2	9.14×10^{-6} (2.32×10^{-6})	Constant	4.9767*** (0.2803)
Size of farm^2	5.75×10^{-7} (1.66×10^{-6})	Fertilizer (kg)	0.00004*** (3.80×10^{-6})		
Fertilizer (kg)	0.00004 (2.78×10^{-6})	Fertilizer (kg)^2	-8.97×10^{-10} (1.38×10^{-10})		
Fertilizer (kg)^2	-7.66×10^{-10} (9.78×10^{-11})	Constant	5.2264*** (0.0272)		
Constant	5.3906*** (0.0233)				

Note: *** significant at 1% level; ** significant at 5%level; *significant at 10%level.

implications. Both measures offer the potential for N reduction on the farms in the form of organic N reductions (i.e. less manure). Table 6 summarises the amount of organic N on the farms under the two case study scenarios and the percentage changes that would be anticipated. A relatively high organic N reduction (20 percent) can be achieved by reducing the number of LU by 20 percent on Irish dairy and dairy other farms; under the LU reduction to achieve 170 kg organic N per hectare on average 19 percent of organic N can be mitigated on affected farms, or 5 percent on average across all dairy and dairy other farms (Table 6).

In order to compare the measures, the average cost per unit of N abated through each measure is presented in Table 7. The average cost per unit N reduced in the scenario reducing LU by 20 percent measure is €9.51 while the cost of complying with the organic N limits is €3.39 per unit of N abated. However, the latter offers relatively small opportunities for N mitigation (20 percent versus 5 percent), which translates into 26,162 tonnes of organic N abated at a cost of approximately €254 million for the scenario with LU reduction by 20 percent and 5,740 tonnes of N mitigated at a cost of €18 million if the target of no more than 170 kg of organic N per hectare was enforced on the dairy and dairy other farms in Ireland. Thus, if specific targets for N reductions were to be introduced, farmers may need to introduce a combination of different measures in order to achieve the targets. The costs of a combination of methods could potentially be higher and are more difficult to assess.

Table 4: Farm and enterprise GM, GO, DC under each scenario

Scenario	FGM	DGM	DGO	DDC	CGM	CGO	CDC	SGM	SGO	SDC
Reduce LU 170 kg	77023 (81260)	73045 (73965)	121145 (122777)	48100 (48812)	3807 (7126)	15860 (28623)	12053 (21497)	171 (171)	246 (246)	75 (75)
Reduce LU −20%	50675 (63779)	44638 (55786)	72137 (89709)	27499 (33922)	5845 (7685)	20841 (24698)	14996 (17013)	192 (308)	555 (676)	363 (369)

Note: the baseline amounts are reported in the brackets, the averages are produced for affected farms only (for example, 'reduce LU170 kg affects only farms that produce more than 170 kg of organic N per hectare').

Table 5: Percentage change in farm and enterprise GM, GO, DC under different scenarios

Scenario	FGM	DGM	DGO	DDC	CGM	CGO	CDC	SGM	SGO	SDC
Reduce LU to 170 kg/ha N	−5.21	−1.24	−1.33	−1.46	−46.57	−44.59	−43.93	0.00	0.00	0.00
Reduce LU by 20%	−21.08	−19.98	−19.59	−18.93	−23.95	−15.62	−11.85	−37.53	−17.99	−1.69

5. Discussion and Conclusion

From an environmental point of view a wide range of N mitigation options are available to decision-makers. However, there is a great deal of uncertainty regarding the economic impacts that these measures would have on individual economic agents and on farm incomes in particular. In this paper a microsimulation model that would help to asses such impacts is developed. A case study analysis of two mitigation measures is explored namely: 1) a stocking rate reduction to achieve a maximum level of organic N of 170 kg per hectare; 2) a 20 percent livestock reduction.

Both measures discussed here could potentially lead to a reduction in N loss from agricultural land. These measures were chosen as they have been the basis of previous studies using other microsimulation models, thus, are suitable for assessing the consistency of our model specification with the existing research literature. The results are compared to the results by Fezzi *et al.* (2008) for a 20 percent LU reduction and Hennessy *et al.* (2005) for a LU reduction to achieve 170 kg N per hectare scenario.

The results of our model are consistent with those previously obtained by Lally *et al.* (2009), Fezzi *et al.* (2008) and Hennessy *et al.* (2005) and confirm that the measures would lead to a reduction in farm gross margins if introduced. In addition our model allows the volume of N mitigated to be assessed and hence an average cost per unit of N mitigated to be calculated. A major limitation of our model is that it does not presently allow for a combination of the mitigation measures to be considered - this may be needed if specific N reduction targets are to be introduced. As a static model, it does not allow for dynamics in farmers' behaviour. Thus, further extensions to the model are necessary to improve the model's capabilities.

Table 6: Changes in N per hectare under different scenarios

Scenario	OrgN	
	Kg/ha	%
Reduce LU to 170 kg N per hectare	164.4 (199.9)	−18.79%
Reduce LU by 20%	115.01 (143.77)	−20.00%

Note: brackets indicate the baseline amounts of organic N per hectare.

The results of the case study scenarios reported in this paper should be interpreted with care as the results of the model are conditional on the validity of the assumptions underlined. The presented results are average results for all dairy farms in the country and hence may obscure differences in the impacts of the considered N mitigation measures for individual farms. Notwithstanding these cautionary remarks, the model represents a considerable advance in determining the costs and other impacts of the mitigation measures.

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Table 7: The average of mitigation measures

Measure	€/N
Reduce LU to 170 kg N Per hectare	3.39
Reduce LU by 20%	9.51

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Economic factors affecting concentrate usage on Irish sheep farms

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ABSTRACT

While comprehensive farm level models for the dairy, beef and cereal sectors have previously been developed, to date, relatively little research has been conducted on the economics of the sheep sector at farm level. Nationally representative farm level data from Teagasc's National Farm Survey (NFS) is used to develop a model examining the economic factors of concentrate usage on Irish sheep farms informed by the current body of literature on pastoral based production systems research. Results from a 2 step random effects panel regression of a demand function for concentrate use with log linear functional form support the established production literature. The demand for concentrates on Irish sheep farms was found to be elastic and thus sensitive to price changes. Farm labour input, fertiliser application, subscription to an extension and research provider and date of lambing were found to be significantly associated with concentrate demand on sheep enterprises. Results from a second model specification indicate the presence of spatially heterogeneous effects of lambing on concentrate demand across regions.

KEYWORDS: Random Effects Model; Concentrate demand; Sheep production

1. Introduction

The evolution in agricultural policy has altered producer priorities in terms of farm structure and consequently farm management practices. Over the past 30 years, high product prices in the EU have encouraged systems with high inputs of concentrate feeds, fertiliser, machinery and associated labour inputs, particularly in the beef and dairy sectors (Dillon, 2007). Sheep production has in general continued to remain relatively extensive in its nature. With successive CAP reforms and GATT agreements, production systems have been required to account for, on the one hand, environmental concerns, particularly in the context of hill sheep farming on commonages (Buckley *et al.*, 2008) and on the other, reduced product prices. This has led to a growing emphasis on production efficiency per unit of output. Thus, to improve profitability on sheep farms, production costs must be examined as closely as flock performance (Flanagan, 2001). In this regard, Irish conditions for biomass production have been identified as having the potential to afford producers a competitive advantage (O'Donovan *et al.*, 2011).

While climatic conditions and thus grass growth vary widely within Ireland, grass has been shown to grow more regularly from spring to autumn in Western Europe (UK, Ireland, Normandy in France) relative to other European regions where grass growth is limited in summer or the grazing season is quite short due to long cold winters (Brereton, 1995; Dillon, 2007; Drennan *et al.*, 2005). As with dairy and beef, systems of Irish sheep production have been developed to exploit this natural advantage with the aim of increasing profitability by reducing costs through increased pasture utilization in the diet of the ewe. Consequently, mid season lowland production is the predominant system on Irish sheep farms with most sheep lambing in the spring to target grazed grass input as the cheapest source of nutrition. Maximising grass utilisation and minimising concentrate input can enhance the competitiveness of pasture-based systems of production, whilst also preserving the rural landscape and promoting a clean, natural, image (Dillon, 2007; Gottstein, 2007; O'Donovan *et al.*, 2011; Teagasc, 2012a).

Results from Teagasc's eProfit Monitor Programme and the National Farm Survey clearly show that sheep production enterprises with well-developed grassland management practices can return gross margins that compare very favourably with other drystock enterprises (Teagasc 2012a, 2012b) Other important empirical findings highlight the number of lambs reared per ewe joined, stocking rate, and the level of concentrate feeding to ewes and lambs (endogenously linked to grassland management) are key drivers of profitability and technical efficiency on Irish sheep farms (Diskin *et al.*, 2011).

With the general trend of sheep output and associated financial returns in decline since the early nineties, there is a growing focus on cost reduction strategies in order to maintain viable producer incomes. In this regard, the low cost of grazed grass relative to silage and/or

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concentrates is of central importance to maintaining and improving profit margins.

This paper seeks to identify the underlying factors affecting concentrate usage on Irish farms in terms of price effects and management practice, including seasonality of production and farm environmental factors so as to better describe the economic behaviour of agents through the actual choices made on Irish farms. An important part of this analysis is an investigation of whether concentrate use varies depending on the choice of breeding cycle and whether these seasonality of production effects vary across regions. To do this a 2 step (Heckman) Random Effects panel data model of concentrate use is specified using NFS variables and log linear functional form based on production theory. A second model specification is proposed to investigate whether there are significant differences in concentrate demand across regions.

The following section highlights the importance of the grazing resource for pastoral based Irish sheep production.

The grazing resource

Past research has highlighted that stocking rates on Irish grassland farms are low considering the high growth potential, whilst there is an associated overreliance on expensive supplementary feeding (Connolly, 1998; NFS, 2012). There exists significant potential to increase output per ha by improving technical performance (Connolly, 1998). Higher stocking rates and consequently higher output is possible by increasing herbage yield/grass growth through greater and/or more efficient use of fertilizers. Evidence based research points to the potential of farm management practices that maximise grazed grass in the diet of the ruminant and thus minimise concentrate use to increase farm profitability and sustainability.

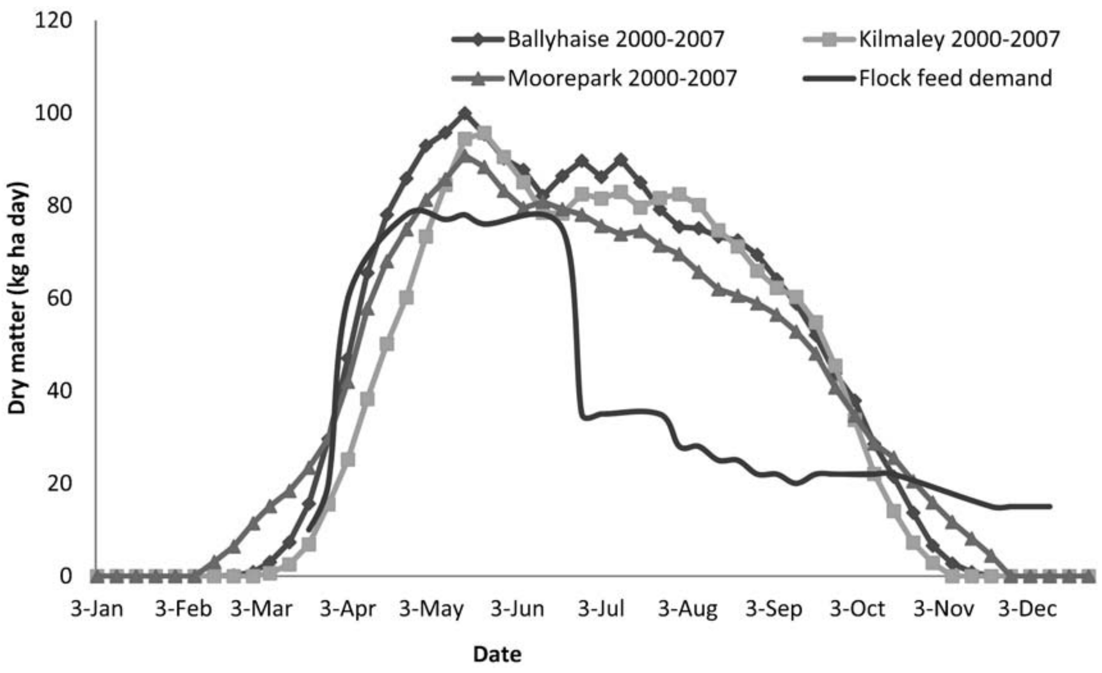
Figure 1 below charts both the nutritional supply of grass and the flock demand for a lowland mid-season farm for a production season. The supply and demand curves visualise the degree to which two key elements of ruminant nutrition interact throughout the year on a 'normal' March lambing mid-season lowland sheep farm. Pasture growth curve measurements are recorded in kilograms of dry matter per hectare for three Teagasc research farms averaged over an eight year period (2000–2007). Moorepark is located in the South, Kilmaley in the West and Ballyhaise in the North of the country.

The typical pattern is low or no growth over the winter months, with significant growth commencing in February or March depending on location and accelerating rapidly up to peak growth rates of approximately 100 kg DM/ha per day and nutritional surplus (Grennan, 1998) in May. In line with grass growth models (Brereton, 1995; Drennan *et al.*, 2005; O' Mara, 2008) figure 1 highlights how both dry matter production potential and the grass growing season varies considerably depending on farm location.

Figure 1 encapsulates many of the dynamics that explain pastoral sheep management and the associated economics of the production system. Accordingly, for any given farm the relationship of the two distributions (grass supply to total nutritional demand) is a key determinant of the firm level production function, expressing as they do combinations of inputs according to a technological relationship (explicitly, the distribution of grass input given grassland management technology and, implicitly, supplementary concentrate input that is required to balance the nutrition demand of the flock given the chosen flock production system).

Initial research involved building a profile of Irish sheep production systems using NFS data with reference to the body of past experimental production and economic research to inform the model of concentrate

Figure 1: Grass growth and feed demand for a midseason lambing flock



demand developed in this paper. The NFS dataset used in this paper is introduced in the following section.

2. Data

The NFS is an unbalanced panel dataset that annually surveys Irish farmers with the aim of: (a) determining the financial situation on Irish farms across the spectrum of farming systems and sizes, (b) providing data on Irish farm output, costs and incomes to the EU Commission in Brussels as part of the Farm Accountancy Data Network (FADN).

The NFS is a random, nationally representative sample selected each year in conjunction with the Central Statistics Office (CSO). Each farm, of which on average approximately 1,000 are surveyed, (922 for the 2012 NFS) is assigned a weighting factor so that the results of the survey are representative of the national population of farms. Utilising the NFS means that data with respect to farm types, their locations and production activities is readily available.

Data cleaning involved the identification of suitable variables within the NFS to accurately capture animal demographic data. Extracting NFS raw data 'check tables' gives a detailed monthly breakdown of animal stocks by age class. 'Notes data' per month for lamb births, deaths, transfers, sales, purchases, etc., which are used to build up reported aggregated NFS variables, was extracted and cleaned into a usable dataset. This data has not in the past been directly manipulated for research purposes and is required here to capture lamb birth dates on Irish sheep farms.

3. Methods and Procedures

This paper uses panel data methods to model concentrate use on Irish sheep farms over time by employing National Farm Survey data on 710 farm observations for a three year period, 2008–2010. While NFS data is available dating back to 1975, the detailed monthly animal demographic breakdowns used in this paper are available since 2008. Using a subsample of the NFS means that the dataset employed is a short panel with relatively few time periods and many individual farms (N=710, T=3). Most farms have multiple observations/ years and thus the number of farms is substantially less than 710. Use of NFS panel data enables issues of heterogeneity and omitted variables, measurement error, dynamics and causality under certain conditions to be addressed (S. Hynes, Dillon, E., Hennessy, T., Garvey, E, 2007).

This study can be characterised as an input demand study based on production theory following the typology developed by Burrell (Burrell, 1989). Consequently, demand for an input, in this case supplementary concentrate feed, is regressed on its own and cross prices and other shift variables, with the results interpretable as Marshallian elasticities of demand. Implicit in this single equation input demand model is an underlying assumption of the profit maximising behaviour of producers (J. Breen *et al.*, 2012; Burrell, 1989). Having constructed a 3-year unbalanced panel of sheep farms, a random effects model of concentrate feed is estimated after first addressing the issue of sample selection bias.

The list of variables specified in this model of concentrate feed use is presented in Table 1 and builds upon previous input demand studies and the current production literature previous NFS research (Connolly, 1998, 2000; NFS, 2012). The dependent variable of choice is concentrate use per sheep livestock units. The NFS concentrates variable captures the quantity of supplementary concentrate fed to sheep livestock per year. In this study livestock units relate to the number of sheep livestock units on farms. As highlighted in the summary statistics of Table 3, a number of farms are shown to purchase no supplementary concentrate feed and are thus completely dependent on forage as a source of nutrition. In this context the dependent variable is censored with a concentration of observations at zero values. Failing to correct for this issue results in biased parameter estimates.

In the following section this paper proposes a two stage estimator to address this selection bias in line with the procedure first proposed by (Heckman, 1976). This approach involves estimation of a probit model for selection, followed by the inclusion of a correction factor in the model of interest. Specifically the Inverse Mills ratio is calculated from a probit selection model and included as an explanatory variable in the subsequent Random effects model of concentrate use.

Correcting for Sample Selection Bias - Heckman 2 Step Procedure

Step 1 - Selection Equation

With their differentiable production systems, some of which are more extensive in nature, it is evident that a subset of farms within the sample makes the production decision not to feed concentrates. In the context of this study, farms that feed concentrates thus represent a non-randomly selected sample (649 obs) from the full set of 710 obs over the period 2008–2010. Modelling the factors that affect concentrate demand by drawing solely on this subset of farms fails to take into account the characteristics of those farms which choose not to feed concentrates, and which may potentially exhibit an alternative preference structure. Accordingly, the dependent variable is censored with a concentration of observations around 0. In order to correct for self-selection a selection equation must first be estimated using the inverse mills ratio (equation 1.2).

The first stage selection equation for this study can be represented as follows:

$$\mathrm{Prob}(D_i = |Z_i) = \Phi(Z_i\gamma) \quad \text{(eq1)}$$

$$\text{where: } D_i = (0 \text{ if } Z_i\gamma + \upsilon_i \leq 0;\ \text{if } Z_i\gamma + \upsilon_i > 0) \quad \text{(eq1.1)}$$

Equation one represents a probit regression where D is an indicator for positive concentrate use. Z is a vector of explanatory variables for concentrate use, γ is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution and υ_i are unobservable sources of variation in D_i. Sample selection bias exists because $E[\varepsilon_i|Z_i, D_i=1] \neq 0$. Consequently, the conditional mean for concentrate use is being misspecified (Vella, 1998). The assumptions

Table 1: Description and summary statistics for model of concentrate use

Variable	Description	Obs	Mean or Proportion*	Std Deviation	Min	Max
Concentrate use per livestock unit	Concentrate use per sheep livestock unit	710	6.82	6.76	0	57.38
Concentrate price	Price of purchased concentrate per tonne (€)	710	237.73	83.68	0	400
Weaning rate	Number of lambs per ewe mated to ram	710	1.11	0.44	0	2.5
Labour intensity	Total labour units divided by farm forage area (lu per acre)	710	0.034	0.024	0.003	0.339
Fertiliser application rate	Rate of compound chemical fertiliser applied to total farm area (kgs per ha)	710	101.45	79.83	0	455.73
Reps participation	0; Not a REPs participant farm 1; A REPs Participant farm	710	0.545	0.498	0	1
Off-farm job	0; Farmer has no off farm employment 1; Farmer has off farm employment	710	0.255	0.436	0	1
Teagasc advisory client	0; No subscription to Teagasc service 1; Subscription to Teagasc service	710	0.585	0.493	0	1
Sheep numbers	Number of sheep in Lu equivalents	710	24.250	30.127	0.02	380.36
Farm Size	Forage Area measured in acres	710	18.280	30.002	0.02	346.3
Lambing date	Percentage of lamb crop born per month					
January		710	0.096	0.221	0	1
February		710	0.207	0.302	0	1
March		710	0.413	0.365	0	1
April		710	0.187	0.296	0	1
May–Dec		710	0.021	0.077	0	.722
Region	Farms belong to one of 8 geographic regions 1–8; see Table 3 for expanded regional breakdown.					
1	Border	710	0.24	0.43	0	1
2	Dublin	710	0.01	0.11	0	1
3	East	710	0.17	0.37	0	1
4	Midlands	710	0.11	0.31	0	1
5	Southwest	710	0.05	0.22	0	1
6	Southeast	710	0.13	0.33	0	1
7	South	710	0.12	0.33	0	1
8	West	710	0.18	0.38	0	1

*Proportion for dummy variable expressed as a percentage of sample where dummy equals 1.

must be made that εi and υ_i are independent and identically distributed and independent of Z_i. Thus a probit model is used to regress Z_i on D_i and to estimate:

$$E[\varepsilon_i|Z_i, D_i=1]=\frac{\vartheta(Z_i'\gamma)}{\Phi(Z_i'\gamma)} \qquad \text{(eq1.2)}$$

Where φ(.) and Φ(.) denote the probability and cumulative distribution functions of the standard normal distribution. The term on the right hand side of (equation 1.2) is known as the Inverse Mills Ratio (IMR). Calculation of the IMR is the first step in the two step model. The second step involves calculating a random effects model of concentrate demand corrected for selection bias through inclusion of the IMR as an explanatory variable in the vector of explanatory variables X_{it}.

The variables contained in the vector of explanatory variables for the selection equation Z_i (equation1.2) and those of the second stage random effects model X_{it} (equation 2,) are overlapping but not identical. X_{it} includes the IMR which accounts for selection bias as specified in (equation 1.2). Z_i on the other hand contains a variable for weaning rate, which is not in X_{it}. Given the production system most likely employed by those 'non using' sheep farms, i.e., farms which do not use concentrate feed, the derived variable weaning rate is used as an identifier for the selection equation. Farms with productive ewe flocks can be guaranteed to witness seasonal surges in nutritional requirements. Farms with alternative production systems, on the other hand, such as farms which may have a significant hogget rearing enterprise, are expected to have low weaning rates and be more extensive with lower concentrate demand (Hoyne, 2001). The weaning rate therefore is proposed to mostly impact upon the first stage decision rather than the second stage. This inclusion of an extra variable in the first step acts as an exclusion restriction and helps to avoid collinearity problems between the IMR and other independent variables in X_{ij} (Greene, 2003).

Step 2 - Demand equation - Random Effects Panel Model corrected for selection bias

To estimate the demand equation for concentrates the following random effects model specification was employed:

$$Y_{it} = \beta_o + \beta X_{it} + (U_{it} + \varepsilon_{it}), \qquad \text{(eq2)}$$

Where Y_{it} is the dependent variable, the quantity of concentrate used per livestock unit per farm i in year t (t=08, 09, 10). X_{it} is a vector of explanatory variables which includes the IMR from the selection equation. (U_{it}+ε_{it}) represents the composite error term (V_{it}). U_{it} is an idiosyncratic fixed effect which takes into account differences in unobservable time invariant characteristics of the farms (Between-entity error term), ε_{it} is the within-entity error term.

From equation 2 concentrate use intensity per farm can be expressed as a function of

$$C = f(P, Z, D)$$

Where the farm level demand for supplementary concentrates feed (C) is a function of the price of concentrates (P), other farm specific variables (Z) and correction for selection IMR (D).

Exploiting the panel nature of the National Farm Survey, this paper estimates a panel data random effects model (Howley, 2012). In terms of the choice of panel estimator, fixed effects allow the individual component to enter through the intercept whereas random effects have the individual component entering through the error term (U_{it} the idiosyncratic error term). Thus a panel rather than a pooled specification is preferable, as the error component for individual farms in the NFS is correlated across years.

The fixed effects estimator uses within group variation in estimation. However, in practice, within group variation may be limited given the nature of the dataset, where there is often very little variability in relevant variables for individual observations (farms) over time. The random effects estimation, on the other hand, weights within and between group variation according to where the variation in X and the variation in the error term lie. Given the structure of the NFS, where there are a lot more individuals than years, a random effects model is most appropriate. While a Hausman test suggests using a fixed effects model, doing so causes observations to drop out of the sample due to this lack of variability across years (S. Hynes *et al.*, 2009). The choice of random effects estimator in this study of NFS data is thus in line with the rationale developed in S. Hynes, Dillon, E., Hennessy, T., Garvey, E (2007). Accordingly, it assumes the unobserved individual effect is uncorrelated with the regressors in the model.

A second model specification is subsequently proposed to examine heterogeneous between group effects on concentrate use. Specifically, model 2 extends the analysis to examine across region differences in lambing and concentrate demand. It is proposed that there is an expectation of variation in supplementary concentrate demand across regions for farms with similar seasons of production. To control for these across regional differences model 2 includes additional interaction terms of Region interacted with Monthly Lambing Percentage (Jan–Apr). The Results of Model 2 are proposed to better inform regional differences in lambing and concentrate usage.

Summary Statistics of Concentrate Model Variables

Summary statistics for variables used in specifying a random effects model of concentrate use on Irish sheep farms are presented in Table 1. The dependent variable of choice is concentrate use per sheep livestock unit. The NFS concentrates variable captures the quantity of supplementary concentrate fed to sheep livestock per year. The dependent variable thus captures the intensity of supplementary feeding on a per livestock basis. In order to estimate the price elasticity of demand for concentrates, the price per tonne of concentrate is included as an explanatory variable. Note that the mean price per tonne of concentrate feed reported in Table 1 is based on all farms in the sample. However, as previously noted, a number of farms do not feed concentrates and are completely dependent on forage as a source of nutrition. To determine the true mean price per tonne of concentrates paid over the period 2008–10 it is necessary to look at the subsample of farmers who fed concentrates. For the observed farms who fed concentrates over the 3 year period 2008–10, the mean price paid for concentrates was €[4]260/tonne. The mean price for concentrates across all farms, i.e., including those farms which do not feed concentrates, is €237.73, which is the average across all farms.

More technically efficient farms have been shown to place a greater emphasis on pasture expenditure rather than supplementary feed (Teagasc, 2012b). Fertiliser use on these forage based farms is for the production of grass, which is the main feed input in pastoral based ruminant production systems. Grass and grass silage is a substitute for concentrate feed and so the rate of application of inorganic fertiliser per unit area is also included as an explanatory variable in the model. Fertiliser applied is a farm level variable and farm level application rate is assumed for the sheep enterprise of mixed farms. This application rate is the sum of chemical fertiliser compounds applied in kgs divided by the total area of the farm in acres. In the model of concentrate use a second derived fertiliser variable, which relates application intensity to stocking density, is included (not included in summary statistics). This derived variable better captures the effective application intensity on a per livestock basis with the expectation that, given the substitute nature of the two inputs, there will be a negative relationship. As with concentrates, not all farmers in the sample applied chemical fertiliser.

Labour intensity per unit forage area is included as a measure of the production intensity with the expectation that increased intensity will be associated with increased input use and thus be positively correlated with the dependent variable. Labour intensity per unit area is calculated as the total number of labour units of the farm divided by the size of the farm. In this calculation for the derived variable 'Labour intensity', forage area is a farm level variable comprising the area of forage crops grown for consumption on the farm adjusted to include the area equivalent of purchased forage. Total labour units are the sum of labour units unpaid plus labour units paid, where one labour unit is equivalent to 1800 hours. No one person can be more than one labour unit even if he /she works more than the 1800 hrs

[4] In late May 2014, €1 was approximately equivalent to £0.81 and $1.37.

allocation. Persons under 18 years of age are given the follow labour unit equivalent: 16–18 years=0.75, 14–16 years=.50 units (NFS, 2012).

Farm size in terms of the enterprise level forage area variable is included as an explanatory variable and would be expected to be negatively correlated with total concentrate demand as grass is a substitute for concentrate feed. The forage area is that area of the farm dedicated to the production of grass for sheep, including rough grazing and adjusted for commonage area. Dummy explanatory variables are included for: REPs participation, off-farm job, Teagasc subscription, year and region.

REPS payments require an adherence to environmental measures as well as a ceiling on fertiliser usage and are typically associated with a lower intensity of production and output (J. Breen *et al.*, 2012). The dummy for off-farm job corresponds to 1 where the farm holder has an off-farm job and 0 where the holder has no off-farm job. There is an expectation that REPS participants and those with an off-farm job would have more extensive management practices and thus have lower input demands.

A farmer is deemed to be a Teagasc client when they have shown to make a subscription payment to the Teagasc advisory service. As a client of a farm research and extension provider, subscribers could be seen as having access to up-to-date best practice (S. Hanrahan, 2010).

A year dummy is used to control for weather, i.e., the effects of particularly severe weather, its potential effects on grass availability and, consequently, dependence on supplementary feeding.

Region dummies control for the influence of geography, associated soil conditions and production system, whether upland or lowland (Burrell, 1989).

Sheep numbers are based on farm sheep livestock units. The NFS variable sheep livestock numbers are calculated from 'check tables' (raw data files which report monthly animal stocks and flows), by multiplying actual monthly numbers by the relevant livestock unit co-efficient. January Lambing date gives the percentage of births attributable to January. 'Check tables' data were manipulated to calculate this derived variable. January lambing, together with those variables that capture the percentage of births for alternative months, are expected to highlight the influence of seasonality of production on concentrate usage for Irish sheep farms. Note that the figures reported in the summary statistics (Table 1) are for the full sample of farms, some of which do not operate a productive ewe flock. Percentages of births per month will be lower accordingly.

4. Results

Model 1

Table 2 presents the results for Model 1. Model 1 estimates concentrate demand using the natural log of concentrates per livestock unit as the dependent variable. The model is estimated by a random effects general least squares regression for three years of NFS data 2008–2010 inclusive Having previously estimated a probit to correct for sample selection bias, the IMR can be seen to enter the model as an explanatory variable.

Concentrate price has a statistically highly significant negative influence on concentrate use, in line with a priori expectations. The coefficient on concentrate price can be interpreted as a cross price elasticity of demand for concentrate given the chosen log linear functional form. (Burrell, 1989) highlights that for single equation econometric models of this type, the set of regressors chosen in specifying the model implies its own *ceteris paribus* conditions and interpretation of elasticities is thus similarly model specific. This study focuses on whether independent variables have a significant impact on the dependent variable and the direction of the sign (whether positive or negative) rather than the magnitude of the coefficient. Similarly the log of labour intensity is highly significant and positive, indicating that, *ceterius paribus*, increased labour input is associated with increased demand for concentrate feed. The Region variable exhibits a negative coefficient for Regions 1 and 4, significant at the 10% and 5% levels respectively. A detailed description of the breakdown of sheep farms across region and discussion of the regional variation in production and concentrate input use on farms is further developed in the following section.

Fertiliser application rate is significant at the 1% level and would indicate increasing concentrate use for increasing fertiliser application, although the interaction term with stocking rate is negative. The interpretation of the impact of fertiliser should be combined. For a moderately stocked farm with a stocking rate of greater than 1.1 life-stock units per hectare, concentrate use declines with increased fertiliser use, reflecting the trade-off between grass and concentrate. For lower stocked farms, the relationship is positive; perhaps reflecting more about the efficiency of those types of farms.

The coefficient for the Teagasc is significant at 10% and negative. A farmer who is shown to be a Teagasc client through subscription payments to its advisory service uses less concentrate per lu. As a client of a farm research and extension provider, subscribers have access to up-to-date farm management best practice which emphasise greater grass utilisation and reduced dependence on more expensive concentrate feed (S. Hanrahan, 2010). Both REPs and off-farm job are statistically insignificant. However, given the extensive nature of the sheep enterprise, it is unsurprising that REPs participation does not significantly impact management practice and reduce input demand intensity. Indeed an alternative input demand study Breen (2012) which looked the elasticity to demand for fertiliser for more intensive dairy production systems, also reported the coefficient on REPs participation as insignificant. Given the nature of sheep farms, which are often second enterprises on the farm, it follows that the division of labour that comes with an off-farm job has no discernible impact on the nutritional management practices of the sheep enterprise. Year dummies and the coefficient for the log of sheep livestock units are insignificant.

January Lambing is the proportion of births in January and is statistically significant at the 10% level. This coincides with a priori expectations that feed demand is higher at a time when feed supply is insufficient or in deficit, coinciding with lambing when the ewes' plane of nutrition is elevated, thus increasing the requirement for supplementary feed in the form of concentrate to meet the nutritional deficit. This is a significant result and agrees with the sheep production literature. Interpreting the coefficient, a 1 percentage point increase in the level of January lambing leads to 7.7% increase in concentrate use per sheep livestock unit. The level of February, March, April, and Later lambing births does not have a statistically significant influence on concentrate feed intensity in model 1. As previously developed, this study hypothesises that seasonality of production has significant effects on supplementary concentrate feeding.

This paper subsequently presents a second model that further develops the discussion of seasonality effects by taking into account the spatial difference across Irish sheep farms by region.

Regional differences in concentrate use on Irish sheep farms

From the initial model specification presented in Table 2, the level of lambing by month is hypothesised as having a statistically significant impact on concentrates usage. From Model 1 only the January lambing proportion has a statistically significant negative impact on concentrate use per livestock unit. This paper now turns to regional differences in lambing date to progress the story of seasonality effects on concentrate use. This paper hypothesises that in addition to seasonality of production being an important predictor, this effect will vary across regions. The justification for this investigation is based on the current production literature (Carty, 2011; Hoyne, 2001; Teagasc, 2012, C) and the results of the cross tabulation of region with month of lambing and concentrate use which indicate regional differences in lambing and concentrate usage on Irish sheep farms. These regional differences are due primarily to agronomic conditions due to weather, soil and altitude that vary substantially, with typically the South and East having better agricultural conditions. As a result optimal lambing patterns from a grass utilisation point of view will vary from region to region.

Summary Statistics for regional breakdown of season of production and concentrate use (Model 2)

Descriptive statistics in Table 3 below present mean seasonal lamb production by month and concentrate usage broken down by region. The results of the cross tabulation indicate regional differences in lambing and concentrate usage on Irish sheep farms. Summary means for monthly production/lambing are based on a subset of the full sample, representing those 657

Table 2: Results of a random effects model of supplementary concentrate feed demand

Results of Model 1 for concentrate feed demand on Irish sheep farms		
Constant	8.855***	(1.247)
Log of concentrate price	−1.115***	(0.204)
Log of labour intensity	0.261***	(0.083)
Region 1	−0.266*	(0.150)
Region 2	−0.478	(0.545)
Region 4	−0.361**	(0.181)
Region 5	−0.195	(0.218)
Region 6	−0.072	(0.168)
Region 7	−0.146	(0.176)
Region 8	−0.238	(0.160)
Log of fertiliser application rate	0.234**	(0.099)
Log of fertiliser application rate * Farm stocking density	−0.210**	(0.098)
Reps participation	0.049	(0.072)
Off-farm job	−0.053	(0.095)
Teagasc client	−0.146*	(0.082)
Log of sheep numbers	0.001	(0.046)
2009 Year	−0.008	(0.067)
2010 Year	0.028	(0.075)
January lambing	0.770***	(0.248)
February lambing	0.289	(0.211)
March Lambing	0.089	(0.203)
April Lambing	0.156	(0.234)
Later Lambing	0.009	(0.473)
Inverse Mills Ratio	−0.021**	(0.009)

Notes:
1. N 648
2. Standard errors in parentheses
3. Significance levels * $p<0.10$ ** $p<0.05$ *** $p<0.01$
4. Regions:
   1. Border - Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan
   2. Dublin
   3. East - Kildare, Meath, Wicklow
   4. Midlands - Laois, Longford, Offaly, Westmeath
   5. Southwest - Clare, Limerick, Tipp North
   6. Southeast - Carlow, Kilkenny, Wexford, Tipperary South., Waterford
   7. South - Cork, Kerry
   8. West - Galway, Mayo, Roscommon

observations with productive ewe flocks over the three year period 2008–10. Similarly, the breakdown of the mean level of concentrates fed per livestock unit is based on the subsample of 649 farm observations that feed concentrates.

Notable results highlight how farm location influences the sheep production system in terms of date of lambing and concentrate usage. In line with the production literature, regions where there is a high proportion of mountain flocks such as in counties Donegal, Sligo, Wicklow, i.e., Regions 1 and 3, tend to lamb later, exhibiting a greater proportion of later lambing vis-à-vis early lambing (Carty, 2011; Hoyne, 2001; Teagasc, 2012b). Also, means of concentrate per livestock unit for the western counties of Regions 1 are below the total sample mean.

In contrast, regions 5 and 6 exhibit relatively higher percentages of early lamb births. This follows expectations whereby such farms (in particular those of region 5) are located in counties which are generally associated with earlier lambing lowland flocks. Furthermore, the means of concentrate per livestock unit for regions 5 and 6, reported in Table 3, are above the total sample mean. The lack of grass growth in winter, when the feed requirements of early lambing flocks is peaking (late pregnancy), leads to nutritional deficits. To rectify grass deficits, it is necessary to provide alternative nutritional sources such as specially sown forage crops for winter grazing or extra concentrate feeds. Either option results in considerably increased feed costs compared with mid-season production. Early season lowland production systems are thus most readily accommodated in tillage areas or areas with an early start to the growing season, i.e. more southerly counties such as those of Regions 5 and 6. On mixed farms with both tillage and sheep enterprises, competing demands for labour in spring are avoided by lambing in winter (Flanagan, 1999). Finally, Region 8 can be seen to have a high percentage of births in March and April (over 71%). The counties of Region 8 are important lowland mid-season producers and exhibit mean concentrate usage per livestock unit below the total sample mean, in line with the production literature.

Summary statistics highlight the variation in seasonal production and concentrate usage, thus motivating an investigation of the spatial difference in lambing and its effects on concentrate use. The aim of the following model is to add to the discussion on the variation in practice on Irish farms across region and production system.

Model 2

The results of Model 2 are presented in Table 4. Results are consistent for with those explanatory variables common to the specifications of both models 1 and 2. Independent variables common to both models exhibit the same degree of significance, sign and general magnitude of the coefficient when explaining concentrate demand.

In Model 2, this paper considers an alternative strategy for examining regional differences: incorporating the interaction terms of region with independent variables for seasonality of production by month (Jan–April). It is hypothesised that doing so gains a spatial difference by identifying differences in seasonal production effects, if any, across region. Only coefficients for significant interactions are presented in Table 4. Significant coefficients for a Month*Region interaction indicate the presence of spatially heterogeneous effects of lambing across regions relative to the reference dropped region.

The coefficient for January lambing*Region dummy indicates how the effect of the level of January lambing on concentrate usage differs across groups. Looking to the results in Table 4, the negative coefficient on January lambing*Region3 interaction, significant at the 10% level, is interpreted as follows: an increased percentage of flock births in the East for January results in less demand for concentrates relative to other regions. This result for the Midlands reflects a relatively small proportion of farmers with more efficient systems who lamb earlier than others in their region, reflecting agronomic considerations, as grass growth is later than for example the Southern part of the country.

The same rationale can be used for the interpretation of the other significant interaction coefficients. Looking at the results for April Lambing, the interaction is significant and negative for all regions except Regions 5 and 6. The coefficient for the regional interactions terms is thus negative and in an opposite direction to the main effect. Results signify that regions 1,3,4,7,8 use less concentrate for an increased percentage of April lamb births relative to the reference dropped regions in the South West and South East. Agronomically the South have better grass growth earlier in the season, but there is a catch up in more Northern regions into later Spring

Table 3: Regional breakdown of season of production and concentrate usage

Region (see Table 2 for key)	N*	N**	Concentrate per livestock unit (kgs)	N***	Percentage of births per month across Region					
					Jan	Feb	March	April	May–Dec	
1	168	157	6.624	151	0.064	0.200	0.469	0.236	0.031	1
2	7	5	4.441	5	0.000	0.334	0.345	0.274	0.047	1
3	119	107	7.601	116	0.047	0.179	0.402	0.332	0.040	1
4	79	67	6.501	77	0.092	0.269	0.451	0.181	0.006	1
5	36	34	9.236	34	0.183	0.371	0.394	0.031	0.021	1
6	88	84	8.617	81	0.162	0.333	0.465	0.038	0.002	1
7	86	80	8.591	81	0.111	0.243	0.356	0.242	0.049	1
8	127	115	7.037	112	0.157	0.129	0.532	0.177	0.005	1
Total	710	649	7.469	657	0.104	0.224	0.446	0.202	0.023	1

Notes: *All farms **Farms which feed concentrates ***Farms with productive ewe flocks.

and Summer. As a result it is more efficient for the southernmost counties to lamb earlier to maximise grass utilisation. Consequently those that lamb relatively later in the season require more concentrate feed. The opposite is true for the North of the country where optimally later lambing will be more efficient, reducing concentrate use relatively.

Model 2 results thus confirm the spatial difference that seasonality of production exhibits on concentrate demand across regions.

5. Conclusions

This paper proposes that a greater understanding of the factors influencing farmer decisions across the breadth of farm systems, sizes and environmental conditions, using nationally representative data, informs the actual choices being made on Irish farms and thus informs the interpretation and direction of farm management research, advisory services and dissemination. As a step towards addressing this information gap in the current research programme, this paper proposes a model of the factors affecting concentrate usage on Irish sheep farms in light of a review of farm profiles. The use of nationally representative data enables this study to analyse the actual choices being made on Irish farms and thus inform the interpretation and direction of farm management research, extension information and dissemination. Results from this paper show that the seasonality of production affects concentrates demand and that a spatial difference exists across regions.

An important feature of the paper is that it combines new information on farmer's actual management choices in terms of lambing date and estimates the effect of seasonality of production on concentrate usage. The approach employed uses NFS panel data to take into account the national distribution of farms across the range of farm systems, sizes and environmental conditions. Results highlight that farmer behaviour is consistent with the current animal science production literature. The demand for concentrates on Irish sheep farms was found to be elastic and thus sensitive to price changes. Farm labour input, fertiliser application, subscription to an extension and research provider and date of lambing were found to be significantly associated with concentrate demand on sheep enterprise. Significant results for the interaction of farm location with seasonal production indicates the presence of spatially heterogeneous effects of lambing on concentrate demand across regions.

There is potential to further develop the study in terms of the cost saving potential of better utilisation of grass relative to concentrate feeding. Results for the models proposed in this paper agree with a priori expectations and point towards the substitutable nature of grass and concentrates. Practices that can be shown to decrease concentrate demand whilst increasing grass utilisation can be quantified to determine their cost saving potential. This model provides impetus for future development of a detailed model of nutrition for the national distribution of sheep farms. There is potential to augment NFS data with biological information, cost functions, and environmental weather data to determine the financial impacts of economic behaviour of rational economic agents as preliminarily described through regression analysis in this study. Much research has already being undertaken in the field of ruminant production systems to complement such developments (Finneran *et al.*, 2010). Furthermore, thanks to the recent geo coding of the NFS, developing spatial analysis data has the potential to supplement the

Table 4: Results of a random effects model of supplementary concentrate feed demand on Irish sheep farms including regional interactions

Results of Model 2 for concentrate feed demand with Regional interaction terms		
Constant	8.870***	(1.244)
Log of Concentrate price	−1.164***	(0.205)
Log of Labour intensity	0.240***	(0.084)
Log of Fertiliser Application	0.196*	(0.100)
Log of fertiliser application rate * Farm stocking density	−0.174*	(0.098)
Reps participation	0.054	(0.072)
Off-farm job	−0.087	(0.094)
Teagasc client	−0.139*	(0.082)
Log of Sheep numbers	−0.012	(0.046)
2009 Year	0.010	(0.068)
2010 Year	0.009	(0.076)
January lambing	0.871*	(0.498)
January lambing*Region 3	−1.519*	(0.795)
April Lambing	3.405**	(1.615)
April lambing*Region 1	−3.170**	(1.610)
April lambing*Region 3	−2.916*	(1.607)
April Lambing*Region 4	−3.803**	(1.648)
April Lambing*Region 7	−3.191**	(1.623)
April Lambing*Region 8	−3.916**	(1.620)
Inverse Mills Ratio	−0.020**	(0.009)

Notes:
1. N 648
2. Standard errors in parentheses
3. Significance levels * $p<0.10$ ** $p<0.05$ *** $p<0.01$
4. See Table 2 for key to regions.

current model with weather data and grass growth proxies to the farm level.

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BOOK REVIEW

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Development Field Work: A Practical Guide

Regina Scheyvens (editor)

Second Edition, February 2014, published by Sage Publications Ltd, London, UK. 312 pages. Hardcover: ISBN 9781446254769, price $130, £85. Paperback: ISBN 9781446254776, price $50, £27.95. E-book: ISBN 9781446297452, price $57, £34.

There have been several texts on issues related to development as the world strives to generate and apply knowledge on development. The quest for development in all spheres of human life has led to several approaches, techniques and practitioners in a seeming maze that is yet to deliver the desired development or at best serendipitous results on development efforts. A major step out of this jungle of practices and attempts is this delivery of a practical approach and learning from practitioners' experiences, albeit not a one-cap-fits-all prescription. The focus on the methodology of implementing all forms of development research both in philosophical and practical terms is very intriguing and educative.

The book is organised into four parts with 13 chapters. The introductory chapter preceding the 13 chapters describes 'the field' as a socio-political and/or geographical site where a researcher spends time collecting data to gain a deeper understanding of development issues. It establishes the fact that where researchers are well-prepared for 'the field' and sensitive to the local context and culture, development fieldwork can be a valuable experience for both the researcher and their research participants. It emphasises that to prepare well for development fieldwork the researcher must give due consideration to practical, methodological and ethical issues.

Part One, described as 'Methodology' consists of Chapters 2, Designing Development Research; 3, Quantitative Research; 4, Qualitative Research and 5, Something Old, Something New: Research Using Archives, Texts and Virtual Data. This section states that philosophical issues are important in research design, particularly matters relating to world- views and epistemology; development researchers should therefore interrogate their starting points and reflect on these issues throughout their research. Good research design helps put in place important fixed elements for research, mainly a clear focus, direction and research question. However, in practice this clear vision and rigid framework need to be balanced by flexibility during the research process to respond to unforeseen obstacles and new opportunities. This section on methods states that quantitative data analysis is usually best used in conjunction with some qualitative techniques when conducting social science research in developing countries, and that no matter the level of sophistication of methods of analysis and complexity of statistical techniques, the results will be worthless if the raw data is flawed. The highlights of the Part include the fact that qualitative approaches typically seek depth rather than breadth of understanding; that co-construction of knowledge, positionality, reflexivity and the relationships between the researchers and researched are critical to qualitative research; and that participatory methods increasingly see communities involved in the co-construction of knowledge and the research process. The discourse on Something Old, Something New: Research Using Archives, Texts and Virtual Data emphasises that archival and internet-based research can be seen as both an extension of the traditional fieldwork and as a field location of themselves, which is as political and as much a part of the 'social terrain' (with all pertaining power inequalities) as the traditional field site and that gatekeepers are of particular importance to archival and virtual research. Identifying the best person to give access to a locked storeroom or private online forum, and approaching them appropriately, can make or break a research project.

Part Two, depicted as 'Preparation for the Field' comprises Chapters 6, Practical Issues; and 7, Personal Issues. The highlights of Chapter 6 include choice of location and timing of fieldwork by weighing up academic enquiry and methodology with practical, health and safety issues as well as ethical considerations, especially when planning on using visual methods, such as photography or filming. Chapter 7 considers the ethical implications with cultural and personal circumstances, as well as issues of representation and context, to avoid possible harm. It is important to note that desirable personal traits for those conducting fieldwork in developing countries include empathy, tolerance, patience, open-mindedness, courtesy, discretion and a willingness to learn.

Part 3, titled 'In the Field', consists of Chapters 8, Entering the Field; 9, Ethical Issues; and 10, Working with Marginalised, Vulnerable or Privileged Groups. Here the book claims not to be a guide as such but a description of practical steps based on experiences of the writers to educate fellow development researchers that culture shock is common amongst fieldworkers, both those going into new environments and those returning to do research at home. This is a normal reaction, and plans to cope with it include time out, contact with loved ones and keeping a personal diary; and since the notion of 'appropriate behaviour' is complex and culturally constructed, a polite, friendly demeanour and careful thought to off-duty and online behaviour will go a long way towards smoothing the fieldwork experience. The 'gold standard' for researchers is full language skills but this is unrealistic for many researchers. It is, however, both respectful and advantageous to learn some of the local vernacular, and to choose an interpreter who speaks the local language as their first language as the researchers strive to ensure that the research process ensures participants' dignity, privacy and safety, and 'gives back' to them in some ways– 'ethics from the bottom up'. Development researchers need to be self-aware and reflexive, especially when working across ethnic, language, class, age and gender lines. Ethical issues often arise due to the potential for misunderstanding in cross-cultural contexts, and the unequal power relations between the researcher and many participants as ethical issues are brought to the fore in research with children, the poor, women and ethnic minorities. Thorough research planning is needed to ensure rewarding experiences for both researcher and participants, with marginalised groups treated as active subjects rather than passive objects of the research.

Part Four, titled 'Leaving the Field', consists of Chapters 11, Anything to Declare? The Politics and Practicalities of Leaving the Field; and 12, Returning to University and Writing the Field. Here the book points out that the experiences of leaving are interwoven with all other phases of research, which have pragmatic, emotional and ethical dimensions that influence field experiences and can generate helpful insights for writing. There is therefore the need to develop appropriate leaving strategies for different relationships and cultural contexts–important to meet ethical responsibilities to participants, others in the field site and to future researchers. This will help development researchers to engage with the ethics and politics of how they choose to represent participants and connect personal experiences with wider social issues while paying attention to questions of positionality and reflexivity. Chapter 13, 'Ways Forward' concludes the book with an exploration of the possibilities of the future of development research.

The writers through the 'gift of the gab' and brilliant advocacy in the temple of development have forged useful approaches in the furnace of practical experiences for the benefit of new, upcoming, emerging and established development researchers.

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