# Understanding crop and farm management

## Links to farm characteristics, productivity, biodiversity, marketing channels and perceptions of climate change

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# Understanding crop and farm management: Links to farm characteristics, productivity, biodiversity, marketing channels and perceptions of climate change


## Abstract

Agriculture faces challenges in meeting rising demand for food, feed, fibre and fuel while coping with pressure from globalisation, limited natural resources and climate change. Farmers will choose management practices based on their goals and available resources and these practices will influence farm performance. The aim of this thesis was to understand farmers' crop and farm management practices and their links to farm(er) characteristics, productivity, biodiversity, marketing channels and perceptions of climate change. Specific objectives were to i) identify factors influencing crop choice and crop rotations on organic farms, ii) evaluate effects of management practices on barley performance indicators, iii) investigate farmers' perceptions and adaptation strategies to climate change, and iv) explore linkages between marketing channels, farm characteristics and biodiversity. Information from semi-structured interviews, a questionnaire, barley growth and yield indicators and biodiversity records were used. In total, 31 farms (9 conventional, 22 organic) were studied in the Uppland province in Sweden. Crop choice and rotation on organic farms were mainly determined by price, need for feed, traditions, biophysical factors and environmental concerns. Arable farmers often grew cereals for their profitability, and their crop choices resulted in rotations that required intensive management to maintain high yields. Barley grain yield was significantly higher on conventional than organic farms, suggesting that chemical fertilisers and herbicides are more effective than organic manures or good crop rotations. Several older farmers (>50 years) perceived a change in climate that they associated with longer growing seasons, extreme weather events and more pests and weeds. To deal with weather variability and climate change, organic farmers tended to use proactive approaches such as crop rotation and diversification, while many conventional farmers shifted sowing and harvesting time and used more crop protection. Farmers sold their products through local, distant and a combination of marketing channels. Farmers selling locally tended to have smaller farms with higher biodiversity than farmers using distant marketing channels. This thesis demonstrates that management practices are often influenced by farmers' goals, experience and farm characteristics. Combining qualitative and quantitative research contributes to better understanding of management practices and their links with farm characteristics, crop yield, climate change adaptation, marketing and farm biodiversity. This knowledge will be useful in regional policies, farm advisory and training.



*Keywords:* biodiversity*,* climate change, conventional farms, crop choice, crop rotation, farm management, marketing channel, organic farms

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# Dedication

To my family

*“Farming is a profession of hope”*- Brian Brett

# Contents

# List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Chongtham, I.R., Bergkvist, G., Watson, C.A., Sandström, E., Bengtsson, J. & Öborn, I. (2016). Factors influencing crop rotation strategies on organic farms with different time periods since conversion to organic production. *Biological Agriculture & Horticulture*. http://dx.doi.org/10.1080/01448765.2016.1174884.

II Nkurunziza, N., Chongtham, I.R., Watson, C.A., Marstop, H., Öborn, I., Bergkvist, G. & Bengtsson, J. Modelling effects of multiple farm management practices on barley performance using Projection on Latent Structures (PLS) (Submitted manuscript).

III Chongtham, I.R., Sandström, E., Bergkvist, G., Watson, C.A., Milestad, R., Thored, K., Bengtsson, J. & Öborn, I. Organic and conventional farmers' perceptions and adaptive measures to climate change, a Swedish example (Manuscript).

IV Chongtham, I.R., Sandström, E., Watson, C.A., Bergkvist, G., Bengtsson, J. & Öborn, I. Exploring links between marketing channels, farming systems, farm size and farmland biodiversity in Central Sweden (Manuscript).

Papers I is reproduced with the permission of the publishers.

The contribution of Iman Raj Chongtham to the papers included in this thesis was as follows:

I Participated in designing the study, carried out the interviews, analysed the interview data and wrote the majority of the manuscript with the guidance from supervisors.

II Participated in carrying out the interviews, analysed the interview data, wrote some sections and commented on the whole text.

III Participated in designing the study, carried out the interviews, analysed the data and wrote the majority of the manuscript with the guidance from supervisors.

IV Participated in designing the study, carried out the interviews, analysed the interview data and wrote the manuscript together with the co-authors.

# Abbreviations

ANCOVA: Analysis of covariance
ANOVA: Analysis of variance
BBCH: Biologische bundesanstalt bundessortenamt und chemische industrie
CF: Conventional Farm(er)
DM: Dry matter
EC: European commission
EU: European Union
FAO: Food and agricultural organization
IFOAM: International federation of organic agriculture movements
IPCC: Intergovernmental panel on climate change
MEA: Millennium ecosystem assessment
OOF: Old organic farm(er)
PCA: Principle component analysis
PLS: Projection on latent structures
SOU: Statens offentliga utredningar
UN: United Nations
VIP: Variable importance in projection
YOF: Young organic farm(er)

# 1 Introduction

The greatest challenge for agriculture in the 21$^{st}$ century is to produce enough to feed the rapidly growing global population while also reducing the effects of farming on natural resources, increasing ecosystem services simultaneously time tackling climate change and market uncertainties (FAO, 2011a). A growing global population, coupled with rapid development in the economy and infrastructure in many parts of the world, is placing pressure on natural resources such as agricultural land, water, air, forests and fossil fuels. Individual farmers have to consider various factors when deciding which crops to grow, how to cultivate the land, how to use available resources and how and where to sell their products. Farmers have to take into account the unpredictable fluctuations in weather and markets, but also meet stricter environmental rules and consumer preferences. Several authors (Gasson, 1973; Granovetter, 1985; Hogan *et al*., 2011) have reported that farmers' management practices are based on a complex set of economic and non-economic goals which are relevant to them at a given time and location. Hence, in order to better understand the management practices of farmers, it is important to identify the diversity of reasons and motivations behind their choices and assess their relevance in the given context.

Organic and conventional farmers may be said to represent two different world views, beliefs or philosophies of agriculture. Organic farmers have been described as having more diverse crops and smaller farms, ecocentric attitudes, and a non-exploitative approach towards farming compared with conventional farmers (Rigby & Cáceres, 2001; Varhoog *et al*., 2003; Vaarst *et al*., 2003; King & Ilbery, 2012). However, this description may not be applicable to all organic or conventional farmers, as they are heterogeneous groups and management practices and philosophies may vary between individual farmers, whether organic or conventional (Mccann *et al*., 1997; Lockie &Halpin, 2005; Darnhofer *et al*., 2010).

Legislation and standards for organic farming restrict the use of certain chemical fertilisers and pesticides. Thus the management of plant nutrients, weeds, pests and diseases on organic farms is likely to differ from that applied on conventional farms and this could be reflected in the yield, farmland biodiversity and how farmers are dealing with climate change and marketing challenges. Furthermore, even within organic and conventional farms, the type of cropping systems, farm products (such as meat, vegetables, cereals and dairy), marketing strategies and experience in farming may result in different farming objectives and crop and farm management practices. Thus, identifying the factors, trade-offs and considerations which farmers take into account for their farm management can improve understanding of the various factors that influence their management practices and how they translate into yields, climate change adaptation, market challenges and farmland diversity. Such knowledge can contribute to formulating effective agricultural policies, providing advisory services and improving economic performance at farm level.

# 2 Aim of the thesis

The overall aim of this thesis was to understand farmers' crop and farm management practices and their links to farm(er) characteristics, productivity, biodiversity, marketing channels and perceptions of climate change. The province of Uppland in Central Sweden was chosen as the study area. Four specific objectives were set out to address the overall aim and each objective was constructed into an individual paper.

Specific objectives were to:

1. Explore crop rotations practiced by farmers with varying experience in organic farming and farm types, identify trade-offs and discuss the rationales of different farmers in relation to the rules for a well-functioning crop rotation and the principles of organic agriculture (Paper I).
2. Evaluate the effect of multiple crop and farm management practices on a variety of farms on several indicators of cereal crop performance (*e.g.* biomass, chlorophyll and nitrogen concentrations at different growth stages, grain yield), and examine whether crop performance (barley, *Hordeum vulgare L.*) can be predicted from information on present and past management practices (Paper II).
3. Investigate different farmers' perceptions of weather variability and climate change and assess their adaptive responses (Paper III).
4. Explore the extent to which farmers marketing channels are related to farming systems, farm size and farmland biodiversity in a limited geographical region, the province of Uppland located in central Sweden (Paper IV).

# 3 Background

## 3.1 Challenges in agriculture

Agriculture in the 21st century faces multiple challenges: it has to meet the demand for food, feed, fibre and fuel, while reducing the environmental impact of production. Further pressure results from rapid growth in population, limited land and fresh water resources and climate change (FAO, 2009; Fedoroff *et al*., 2010). In addition, declining ecosystem services have been attributed to current agricultural management practices and there have been calls for a reduction in the intensity of management practices, in order to restore/improve the degrading ecosystems (MEA, 2005; Lobell *et al*., 2008). The magnitude of the impacts of climate change on agriculture will differ between regions and this will be further affected by other changes, pressure on land resources, globalisation and consumption pattern (Lobell et al., 2008; FAO, 2011b). Like other parts of the world, agriculture in Sweden will also be affected by climate change, although to varying degrees (UN, country report). In their strategic analysis of Swedish agriculture, Fogelfors *et al*. (2009) identified important challenges for Swedish agriculture in the 21$^{st}$ century. The most important challenges they cited were the effects of climate change (such as extreme weather events, risk of pathogen attacks and nutrient losses, *etc*.), reducing the dependence on non-renewable natural resources (such as fossil fuels and provide more ecosystem services) and the risk of decreasing profitability and farmland area due to trade globalisation and liberalisation. In the face of these challenges, farmers have to develop strategies and make decisions for a robust farming system that is not only able to withstand disruptions, but can also contribute to better economic, social and environmental benefits, which are the key prerequisite for the long-term sustainability of their farms.

## 3.2 Management practices of organic and conventional farmers

According to Dury *et al*. (2013), the cropping plan does not emerge from a single factor, but from a dynamic decision-making process which incorporates various factors such as some unplanned decisions to respond to unanticipated situations and/or market opportunities. In order to analyse farmers' management practices, it is important to understand the motivations, and goals of farmers, as well as the underlying bio-physical factors which influences or can influence their practices (Ilbery, 1991). Organic farming is widely perceived as being more environmentally friendly and sustainable than conventional farming, but the opposite view is also common (Buck *et al.,* 1999; Guthman, 2004). The difference in the management practices and attitudes of organic and conventional farmers have been described by many authors (Lampkin & Weinschenk, 1996; Fuller, 1997; Koesling *et al*., 2004; Darnhofer *et al*., 2005; Kings & Ilbery, 2012; Blom-Zandstra & Gremmen, 2012). Fuller, (1997) and Kings & Ilbery, (2012) reported that organic farmers tend to have diverse farms, aim to mimic natural systems and have great respect for nature. Many are also well rooted in the philosophies of organic agriculture, which is based on the rejection of synthetic fertilisers and pesticides, while seeking to close nutrient cycles and improve soil and plant health. The conventional farmers, on the other hand, are reported to have larger and more specialised farms, technocentric attitudes, and focus more on efficiency, high production and protection of crops and livestock by using external inputs (Koesling *et al*., 2004; Hole *et al*. 2005; Darnhofer *et al*., 2005; Storkey *et al*. 2011;Blom-Zandstra & Gremmen, 2012). However, Buck *et al*. (1999), Padel *et al*. (2009) and Darnhofer *et al*. (2010) point out that although organic farming, at its conception, was associated with a production process that was small scale, environmentally friendly, and socially conscious, there is increasing evidence that a number of organic farmers in Europe and elsewhere are implementing practices which are similar to those in conventional farming, such as growing a limited number of crop species, relying heavily on external inputs. Their practices comply with the organic certification standards, but not with the principles of organic farming[1] laid out by International federation of organic agriculture movements (IFOAM).

Corresponding cases of some conventional farmers employing sustainable practices and having ecocentric attitudes were reported by Comer *et al*. (1999) and Darnhofer *et al*. (2005). This heterogeneity even within particular farming

[1] Detailed description of the four principles of organic farming: Principle of health, ecology, fairness and care, laid out by IFOAM can be found at http://www.ifoam.bio/en/organic-landmarks/principles-organic-agriculture

systems suggests the importance of understanding individual farm management practices. Despite, the importance of studying farmer's management practices at individual level, one must not ignore the important inherent differences between organic and conventional farming practices, such as the use of chemical inputs in conventional farming systems (Lee, 2005). In organic practices, synthetic chemicals such as mineral fertilisers, herbicides, pesticides and antibiotics are prohibited, and stricter rules for better animal welfare and environmental benefits specified in country or regional standards must be complied with. Because of these rules and regulations, there is some evidence showing that organic farmers tend to use a strategically different approach to conventional farmers, because they rely on long-term solutions (preventative rather than reactive), *e.g*. crop rotation to reduce weeds, pest and diseases (Watson *et al*., 2002; Kasperczyk & Knickel, 2006). Conventional agriculture often relies on external inputs, *e.g*. application of chemical fertiliser or herbicide. Several studies have reported that organic and conventional farmers perceive risk differently (Flaten *et al*., 2005) and pursue different strategies to adapt to risks and local conditions (van Mansvelt *et al*., 1998). Thus, the differences in farmers' approaches and practices are likely to influence their farm management in terms of e.g. crop choice, management practices or when dealing with climate and market conditions.

## 3.3 Climate change in Sweden and its implications for agriculture

According to Intergovernmental Panel on Climate Change (IPCC, 2007), climate change refers to a change in the state of the climate that can be identified (*e.g*. statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Climate change will have considerable consequences for agriculture, ecosystem function and human health on a global scale (IPCC, 2007).

In Sweden, the average annual air temperature has increased by about 1°C in the past 20 years, compared with the average temperature for 1960-1990 (Rummukainen, 2010). This increase in temperature is likely to increase the problems with weeds, pests and diseases in agriculture (Eckersten *et al*., 2008). With climate change, temperatures during winter are forecast to be milder, summer to be warmer, spring seasons to start earlier and the autumn period to be longer. Furthermore, extreme weather events such as high/low temperature, high precipitation causing flooding and drought are all projected to occur more frequently. Precipitation is expected to increase in autumn, winter and spring (Lind & Kjellström, 2008). The length of the growing season is projected to increase in all parts of the country, so the conditions for food production in Sweden are projected to become more favourable in terms of potential productivity (Eckersten *et al*., 2010; Trnka *et al*., 2011). However, the adaptation measures to climate change are also likely to put more pressure on the environment through increased use of nutrients, chemicals and other inputs due to increasing risk of flood, drought, pest and diseases (Eckersten *et al*., 2008; SOU, 2007). As shown in Figure 1, fluctuations in yearly precipitation and air temperature can be high and these might have implications for agriculture in Sweden. For example, extreme fluctuations in rainfall can potentially increase risk leaching of soil nutrients due to heavy rain and flooding, while fluctuations in temperatures during winter months can cause more outbreaks of fungal diseases, leading to poor survival of winter cereals, and will affect the planning of farm operations (Fogelfors *et al*., 2009). However, all these claims on the effects of climate change on Swedish agriculture have been based on predictions and modelling tools, and there is a lack of information on how Swedish farmers perceive climate change and how they have dealt, or are dealing, with climate change.

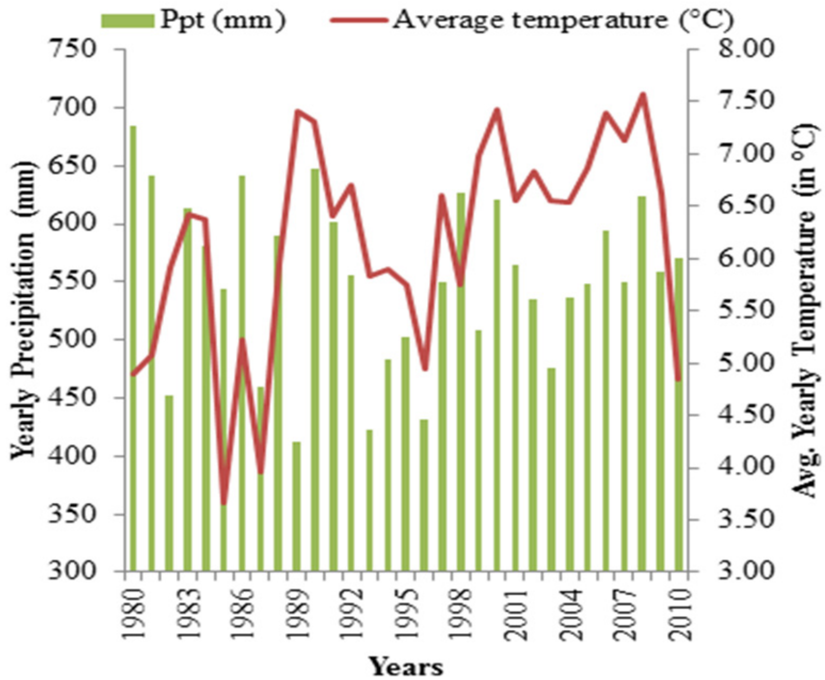



*Figure 1*. Yearly precipitation and mean yearly temperature at Ultuna climate station in central Sweden, 1980-2010. Source: Ultuna Climate Station (unpublished).

## 3.4 Scales in farming and marketing

The increase in scale and specialisation in farming happening in many parts of the world is predicted to threaten the heterogeneity and biodiversity of agricultural landscapes and the existence of small-scale farmers (Pimentel *et al*., 1992; Krebs *et al*., 1999; Norberg-Hodge *et al*., 2002; Smithers *et al*., 2008; Le Roux *et al*., 2010). Because of the growing evidence of the negative effects of large-scale industrial farming on society and the environment, several scholars have called for small-scale local food systems, presenting them as an alternative to the mainstream food system and an alternative vision of social-ecological relations embedded in food (Allen *et al*., 2003; DuPuis & Goodman, 2005). However, small-scale local food systems are also associated with low volume of production, low profitability, high labour cost, less efficiency in selling and distribution and more wastage of food. (Bellows *et al*., 2001; Born & Purcell, 2006; Hardesty, 2007; Silva *et al*., 2008).

The development and direction of Swedish agriculture is also linked to the global food and feed market, as well as national and regional (EU) policies. Farmers are facing challenges with remaining profitable, as the return per hectare of land and animal has declined considerably during the past two decades due to imports of cheaper food products. Many farmers in Sweden have abandoned farming and the number of holdings has decreased, from 96,560 in 1990 to 71,091 in 2010 (Statistics Sweden, 2011; Andersson & Wachtmeister, 2016). Since 1990, the number of farms with cattle and pigs has decreased from 47,292 to 21,586 and 14,301 to 1,695, respectively. The remaining farmers have increased their scale in terms of area and number of animals, in order to become more competitive and viable (EC, 2014; Statistics Sweden, 2011). This increase in scale and specialisation has also been associated with loss of biodiversity: decreasing populations of birds and beetles (Josefsson *et al*., 2013) and lower crop diversity (Björklund *et al*., 2009). Despite this trend for larger and more specialised farms, there are growing numbers of consumers in Sweden who are willing to pay a higher premium for food products which are locally, organically and/or ethically produced (Nilsson, 2009; Engström, 2011; Olsson, 2015). Thus the different scales in farming and marketing seem to have both positive and negative sides for farmers.

## 3.5 Interdisciplinarity in studying farm management practices

According to Newell (2001), interdisciplinary studies bring together distinctive components of two or more disciplines and synthesise a more comprehensive understanding. The work described in this thesis combines knowledge and methods from different disciplines (Nuijten, 2011) since farming are a socio-ecological system. Agriculture production can be modelled as a biophysical process during experiments, but when it comes to 'farm' level; they are not only businesses, but also homes, where owners lives and derive other services. Thus natural sciences (such as agronomy, veterinary science, entomology, etc.) are often not sufficient to understand the farming systems (Duffy *et al*. 1997). Alrøe & Kristensen (2002) referred farming as an agro-ecological system, and concluded that the complex agroecosystem interactions, as well as the practices of farmers in social systems need to be studied to understand farming systems.

To understand management practices in relation to crop choice, climate change, marketing and biodiversity, not only knowledge from different disciplines, but also the integration of these knowledges is required.

# 4 Materials and methods

## 4.1 Study area and selection of farms

The study was carried out in the province of Uppland (Figure 2), which is located in east-central Sweden. Administratively, the province comprises the county boards of Uppsala and Stockholm. Uppland has relatively flat topography, with the highest elevation point only 117 m above sea level. Agriculture in the region is characterised by cereal growing on the open plains and more livestock and mixed farming with a high percentage of rotational or improved grassland (grass-clover) in more forested areas. Rotational grass-clover covers about 41% of the arable land, while winter wheat and spring barley each constitute about 15% of the arable land area (Statistics Sweden, 2011). The major soil type found on agricultural land in this region is Eutric Cambisols (Sarapatka, 2002) with high clay content and, on average, 3.5% total carbon, 0.31% total nitrogen and a pH of 6.6. The mean annual air temperature in the study region during 1980-2010 was 6.2 °C and mean annual precipitation was 552 mm (Ultuna Climate station). The area is prone to drought in early summer (May-June), but the precipitation is generally higher in late summer and autumn. Mean monthly temperature during the cropping season (May-October) is 12.1 °C, according to data recorded at Ultuna climate station.

This thesis work was part of a project titled 'Effect of land use change on multifunctionality in agroecosystems: Biodiversity and ecosystem services after transition to organic production' (funded by the Swedish Research Council, Formas). Within the project, 30 farms (20 organic farms with different time since conversion and 10 conventional farms) located in Uppland province and distributed along a landscape gradient (defined by proportion of arable land within a 1 km radius) were studied. From these farms, 24 farms (16 organic and 8 conventional) were selected for this thesis as some of the farmers were not available for this study. The organic farms had been certified organic under the Swedish organic trademark scheme KRAV and were spread over a time period of 3-25 years since conversion. Paper I presents results from 16 organic farms as the crop choice and rotations were more diverse among this group of farms. In Papers III and IV, the study results are from all 24 farms (16 organic and 8 conventional). In Paper II, only farms with at least one spring barley field 2012 were included. Thus additional farms with spring barley fields, in particular young organic farms, were selected as the aim was to study the management practices and barley performance indicators in young and old organic farms and conventional farms and some of the originally selected farms did not grow spring barley in the year of the study. Thus, in paper II, the results are from 17 farms growing spring barley in 2012 (5 young organic, 6 old organic and 6 conventional). Hence, results from a total of 31 farms (22 organic and 9 conventional) were used in this thesis. A higher number of organic farms were included in order to include both farms recently converted to organic agriculture (young organic farms, YOF) and older organic farms (OOF). The farms were located between 60°02'-59°39'N and 18°16'-16°52'E (Figure 2).

*Figure 2.* Map of Sweden showing the province of Uppland, the study region (in darker shade).

The farms were selected based on organic/conventional, time since conversion to organic agriculture and location reflecting the landscape structure, *i.e.* the proportion of arable land within a set radius (Jonason *et al*., 2011; Rader *et al*., 2014). Conventional and organic farms with different time since conversion to organic agriculture were selected in the different landscape types, in order to avoid overrepresentation of conventional farms on the open plains and of organic farms in the more diverse landscape. An overview of the farms studied is presented in Table 1.

Table 1. Overview information of the farms and farmers that were studied: Gender, age and education of the interviewees were documented as well as the production system (conventional or organic), farm size, main enterprises and farm type.

| Farms (years since conversion) | Paper | Size * (ha) | Gender | Age group (yrs) | Enterprise |
|---|---|---|---|---|---|
| O (25) | I,II, III, IV | 90 | m | 60-70 | Oats, barley, 50 dairy |
| O (25) | I, III, IV | 179 | m, f | 50-60 | Wheat, oats, 20 dairy, 10 beef, 80 sheep, 110 pigs, 350 hens |
| O (23) | I, III, IV | 85 | m, f | 50-60 | Wheat, 22 beef, 33 sheep |
| O (23) | I,II, III, IV | 34 | m,f | 50-60 | Barley, 35 beef |
| O (20) | I,III, IV | 70 | m | 50-60 | Wheat, oats |
| O (18) | I,II, III, IV | 150 | m | 30-40 | Wheat, barley |
| O (13) | I, III, IV | 105 | m,f | 40-50 | Barley/pea, wheat, 90 dairy cows |
| O (12) | I, III, IV | 163 | m | 40-50 | Wheat, beans, 20 sheep |
| O (12) | I, III, IV | 235 | m | 50-60 | Wheat, beans |
| O (12) | I, III, IV | 310 | m | 50-60 | Wheat, barley, 280 dairy cows |
| O (11) | I, III, IV | 180 | m,f | 40-50 | Wheat, oats, beans, 150 beef |
| O (10) | I, III, IV | 55 | m | 30-40 | Wheat, oats, peas |
| (10) | I, III, IV | 220 | m | 50-60 | Wheat, rye wheat, mix grains, 30 beef |
| O (5) | I, III, IV | 75 | m | 40-50 | Cereals, 21 dairy |
| O (4) | I,II, III, IV | 50 | m | 30-40 | Oats, barley/peas, 60 sheep |
| O (3) | I,II, III, IV | 145 | m | 40-50 | Oats, barley, wheat, peas, 50 pigs |
| C | III, IV | 120 | m | 40-50 | Wheat, rye, oats, barley, rape |
| C | II, III, IV | 320 | m,f | 40-50 | Barley, oats, wheat, peas, rape, 25 beef |
| C | III, IV | 77 | m | 40-50 | Wheat, barley, oats |
| C | III, IV | 50 | m | 30-40 | Wheat, oats, some piglets |
| C | II, III, IV | 239 | m | 60-70 | Wheat, barley, peas, rape |
| C | II, III, IV | 640 | m | 50-60 | Wheat, barley, oats, rape, 70 beef |
| C | II, III, IV | 77 | m | 40-50 | Wheat, rape, barley |
| C | II, III, IV | 540 | m | 30-40 | Wheat, barley, oats, rape, 200 beef, 90 dairy |

O= organic farms; C = conventional farms; m= male; f=female

[a] see Paper II for additional farms that were included in that study. Their information are not included in this table as only the management practices, and data relating to barley performance were collected through questionnaire and field measurements.

*Agricultural land including arable and grazing land areas (excluding forest)

**Type= based on the production system and the main source of farm income, farms were classified as arable, beef, pig, dairy, sheep or mixed.

***Mixed = farm income coming from different livestock components as well as from cereals

## 4.2 Semi-structured interviews

As the central research objectives of Paper I, III and IV were to explore farmers' management practices in relation to crop choice, and their perceptions and management strategies in relation to climate and marketing channels, it was decided to use semi-structured interviews with the farmers to collect qualitative information. The interviews were carried out on the farms in spring 2011, mostly in English. The interviews that were carried out in Swedish (n=7) were translated to English. The interview questions were based on key words (see Papers I, III, IV)) and tested with one farmer (not within the group of farmers interviewed), and necessary changes were made and then used for conducting the 24 interviews. Probing was done wherever necessary to obtain information required for the different objectives. The interviews lasted between one and three hours and farmers included both males (n=24) and females (n=6), with both a male and a female being interviewed on six farms. Most of the interviews were carried out inside the farmhouse, with the farm owner(s). On a few occasions, the interviews were conducted outside the house. On many farms the field and livestock units were also visited and the farmers showed what they were doing, which gave an additional opportunity to enquire further, when necessary. All interviews were recorded and transcribed.

## 4.3 Analysis of the interview material

Following the guidelines of Kvale (1996), analysis was done by structuring, condensing, categorising and interpreting the transcribed information. In order to bring out the qualitative aspects of the materials, the software 'Atlas.ti' (manufactured by ATLAS.ti GmbH, Germany) was used. This software helped to condense, structure and categorise the different statements of the transcribed information.

## 4.4 Questionnaire survey

A questionnaire survey was conducted in late 2011 and early 2012 to obtain data on the recent past and present management practices on a given barley field for each of 17 farms (Paper II). Questions were directed to understanding the management at the whole farm level, with particular focus on the management practices during the period 2009-2012 on one field per farm where barley was grown in 2012 (see questionnaire in Paper II).

## 4.5 Barley fields and performance

For Paper II, a sub-set of farmers growing spring barley on at least one field was selected. In 2012, spring barley performance was recorded on these farms. Barley performance included dry matter (DM) of biomass, nitrogen concentrations on two occasions, at growth stages 31 (stem elongation) and 87 (ripening: hard dough) according to the BBCH code (Lancashire *et al*., 1991). Biomass samples were cut at 5 cm height above the ground from an area of 4 * 0.25 $m^2$ and oven-dried at 60°C for at least 24 hours. The dry matter weight was then determined and the nitrogen concentration analysed. In addition, SPAD measurements (an index of chlorophyll content) were taken with a hand-held meter (SPAD 502 Plus) on a weekly basis from 4 June to 16 August. Percentage weed cover was also estimated. At BBCH 87, the number of ears per sample was counted. The nitrogen concentrations were determined using an elemental LECO 2000CN analyzer.

## 4.6 Survey of herbaceous plants and butterflies

Data on species richness of plants and butterflies collected in a previous study by Jonason *et al*. (2011) on the study farms in 2009 were used in Paper IV. In that study, species richness of herbaceous plants including grasses (hereafter referred to as plants) was determined for 10 inventory squares, 0.3 m × 0.3 m, evenly distributed in the field margin at around 0.25 m from the field border and another 10 squares along within-field transects, which were at 1, 5, 10, 20 and 40 m from the field border, resulting in a total of 20 inventory squares per farm.

Surveys of butterflies (*Rhopalocera*) and burnet moths (*Zygaenidae*) (hereafter collectively referred to as butterflies) in Paper IV were made using a modified version of the widely implemented survey method 'Pollard walk' (Pollard & Yates, 1993), and all butterflies 5 m ahead, 5 m into the field and 1.5 m into the field margin were identified to species level.

## 4.7 Statistical analyses

In Paper II, projection on latent structures (PLS) regression analysis, which is an extension of principal component analysis (PCA) (Eriksson *et al.*, 2006a), was used to obtain information on the relationship between barley performance (Y-matrix, 7 variables) and management practices (X-matrix, 29 variables). Each farm was considered an observation and the field-level mean values of crop performance were used in the analysis. The filter method with variable importance in projection (VIP) for variable selection (Eriksson *et al.*, 2006b; Mehmood *et al.*, 2012) was used. It meant that after the first model run including all 29 X-variables, all variables with a VIP less than 1 were eliminated. A second model was then run with the remaining variables. The PLS analyses were performed with the software SIMCA-P V 13.0 (Umetrics, Umeå, Sweden).

In Paper II, analysis of variance (ANOVA) was used to differentiate the effect of farming system on barley performance. Both simple regression and analysis of covariance (ANCOVA) was used to examine the effects of farming system on SPAD values. Growth stages up to 80 on the BBCH scale were considered. The statistical software R, version R3.0.2 (Core-Team, 2013), was used for simple regression, ANCOVA and ANOVA.

In Paper IV, the links between marketing strategies and farm size, landscape and biodiversity measures were explored for each variable separately, using GLM (JMP 11.0, SAS institute; Poisson distributions and log-link function).

# 5 Results

## 5.1 Reasons behind crop choice and crop rotation by organic farmers (Paper I)

The results showed that the crop choice and crop rotation of organic farmers were determined not only by the price and need for feed, but also by their easiness to grow and sell, traditions and environmental concerns. Based on how crops were rotated on the farms included in the study, three different crop rotation strategies were distinguished; strict, flexible and liberal. Farmers practising strict crop rotation strategies had a pre-planned crop sequence and followed the sequence stringently through several rotations. Farmers with flexible crop rotation strategies also had a pre-planned crop sequence, but the crop species in the sequence sometimes varied and changed to adapt to environmental conditions and economic considerations (especially cereal price). Finally, farmers practising liberal crop rotations lacked crop sequence plans and chose crops according to the market price, seed availability, personal preference and weather conditions. Several recently converted organic (YOF) farmers practiced a strict crop rotation and their strategy appeared to be mainly related to controlling weeds and diseases in the cereals (Table 2). Flexible and liberal crop rotation strategies were more associated with long-term organic farmers (OOF) and their rationale was to adapt to, or gain from, the changing conditions such as market and weather.

The arable farmers studied reported a preference for growing cereal crops rather than perennial ley or annual legumes as the cereal crops were more profitable and also as they did not have livestock to consume forages or grain legumes. Most of the livestock farm in the study region, excluding the dairy farm, had the features of 'mixed farms', as their crop rotations were based on producing feed for the livestock as well as cereals for earning direct cash income. This diversification of income sources was most evident amongst the long-term organic livestock farmers (OOF, more than 10 years of certified organic farming) within the group. Their farming aims were to produce sufficient feed and different cash crops. The recently converted organic (YOF) livestock farmers tended to be specialised and focused on producing feed for their livestock and grew few crop species. OOF had more diversified systems in terms of crops species and livestock than YOF.

Table 2. *Summary of general characteristics of the organic farms studied and farmers' crop rotations, typical sequence of crops grown, and type of rotation strategy, i.e. strict (always the same crops grown in rotation if possible), flexible (aim for a special rotation and adjust according to circumstances) and liberal (no special rotation). Farms were sorted according to type (main source of income) and time since conversion to organic farming. Ley refers to a crop mixture of clover and grasses. All crops except winter wheat and triticale are spring-sown*

| Farm no. | Farm type | Farm size (ha) | No. of livestock | Year since conversion to organic | Crop rotation/typical sequence | Rotation strategy |
|---|---|---|---|---|---|---|
| 1 | Arable | 70 | 0 | 20 | Ley, winter wheat, oats, barley | Liberal |
| 2 | Arable | 150 | 0 | 18 | Barley (under-sown ley), ley, ley/black fallow[1], winter wheat, winter wheat | Strict |
| 3 | Arable | 235 | 0 | 12 | Mostly winter wheat and other cereals, but occasionally also field beans | Liberal |
| 4 | Arable | 163 | 0 | 12 | Barley (under-sown with ley), ley/black fallow[1], winter wheat, winter wheat, field beans | Strict |
| 5 | Arable | 55 | 0 | 10 | Oats (under-sown), ley, wheat, oats/peas | Flexible |
| 6 | Dairy | 90 | 50 | 25 | Spring barley/oats (under-sown ley), ley, ley, winter wheat | Strict |
| 7 | Dairy | 105 | 90 | 13 | Barley and peas (under-sown ley), ley, ley, ley, winter wheat | Strict |
| 8 | Dairy | 310 | 280 | 12 | Barley/peas/field beans (under-sown ley), ley, ley, ley, winter cereal (wheat/triticale) | Flexible |
| 9 | Dairy | 75 | 21 | 5 | Winter wheat/triticale (under-sown ley), ley, ley, winter wheat | Strict |
| 10 | Beef/sheep | 85 | 22 beef, 33 sheep | 23 | At least two years of ley and also other crops such as winter wheat, barley | Liberal |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | and oats | |
| 11 | Beef | 34 | 35 | 23 | Cereals, mostly barley, and ley | Liberal |
| 12 | Beef | 180 | 150 | 11 | Oats (under-sown ley), ley, ley, ley, winter wheat, oats, field beans | Flexible |
| 13 | Beef | 220 | 30 | 10 | Mixed grains (under-sown with ley), ley, ley, winter wheat, spring wheat | Strict |
| 14 | Sheep | 50 | 60 | 4 | Oats (under-sown ley), ley, ley, ley, oats/peas | Strict |
| 15 | Mixed | 179 | 110 pig, 20 dairy, 10 beef, 80 sheep, 350 hen | 25 | Barley (under sown ley), ley, ley, winter wheat, oats, peas, winter rye | Flexible |
| 16 | Pig | 145 | 50 | 3 | Oats (under-sown ley), ley, ley, winter wheat/spring barley, oats, peas | Strict |

[1]Short period with black fallow to control perennial vegetative weeds between incorporation of ley crop and sowing of winter wheat.

## 5.2 Barley performance indicators (Paper II)

Management practices at farm and field level on different farms were correlated with grain and straw yield, and with nitrogen concentrations in the barley crop. Among the 14 most important management practices retained from the model, five were related to the whole farm level, two were related to management operations at the field level conducted 2009-2011 and seven were management operations conducted during the year of the study, 2012. The importance of individual management practices within each group is given by the variable importance in projection (VIP) values in Table 3. The PLS analysis also showed similarities and correlations between management practices and barley performance. For example it grouped the six OOFs together according to their management practices, and related this to high nitrogen concentrations in barley grain. Crop biomass and the number of ears and grains were found to be related to use of chemical fertilisers and herbicides on conventional farms.

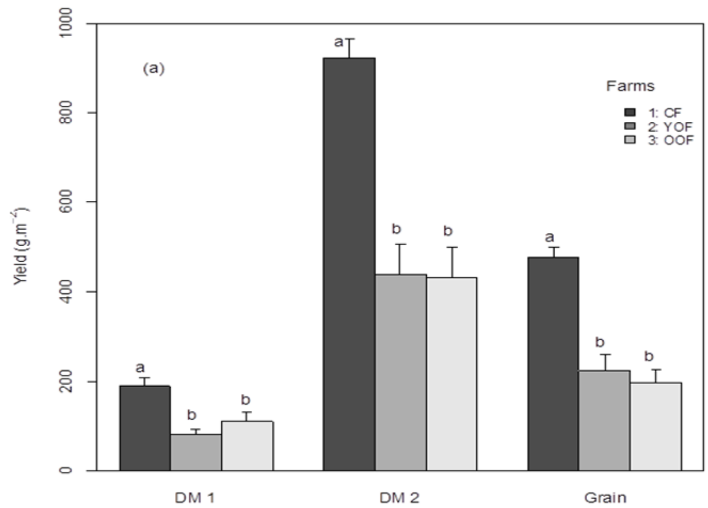
Table 3. *Ranking of the retained management practices, according to their variable importance in projection (VIP*), of the second partial least squares (PLS) model. The standard error (cvSE) of the VIP after cross-validation of the PLS model is also given*

| Management practice | Symbol | Rank | VIP | cvSE |
|---|---|---|---|---|
| *Farm level* | | | | |
| Proportion of other crops** | Ocrops | 5 | 1.09 | 0.87 |
| Proportion of leys | Leys | 7 | 1.04 | 0.49 |
| Proportion of arable land (1 km radius) | PC1 | 8 | 0.96 | 1.14 |
| Time since transition | TST | 10 | 0.90 | 0.51 |
| Presence of pasture on farm | PP | 14 | 0.82 | 0.56 |
| *Field level 2009-2011* | | | | |
| Application technique for organic fertilisers | OFe-AT | 2 | 1.12 | 0,62 |
| Mineral fertilisers used | Min-N | 12 | 0.87 | 0.69 |
| *Field level 2012* | | | | |
| Leys as preceding crop | PC-leys | 1 | 1.14 | 1.14 |
| Cereal as preceding crops | PC-cereal | 3 | 1.11 | 0.64 |
| Straw and crop residues left in the field | SRM-12 | 4 | 1.11 | 0.74 |
| Use of pesticides in 2012 | Pest-12 | 6 | 1.08 | 0.77 |
| Percentage weed cover | Weed | 9 | 0.95 | 0.25 |
| Barley undersown | US-12 | 11 | 0.88 | 0.39 |
| Amount of mineral N | Min-N12 | 13 | 0.83 | 0.67 |

*Note that VIP does not indicate whether the effect is positive or negative, and that it relates to the whole model rather than the effect on individual barley performance.

**Other crops include oilseeds, sugar beet and others that were not mentioned.

The average grain yield of conventional farms was 4.8 ± 0.7 t $ha^{-1}$, which was significantly higher than grain yields of OOF and YOF (2.0 ± 1.0 and 2.2 ± 0.4 t $ha^{-1}$), respectively. In addition, the above-ground plant DM at both development stages (BBCH 31 and 87) was significantly higher on conventional farms than on OOF and YOF (Figure 3a). Nitrogen concentrations in the shoots at the stem elongation BBCH 31 (N-bio-I) and in grain at the ripening (BBCH 87) were lowest in YOF and highest in OOF (Figure 3b). Straw from conventional farms and OOF had higher nitrogen concentrations than straw from YOF. However, the SPAD-values, *i.e.* chlorophyll content, were not related to farm type (P =0.53) or development stage (P =0.11).



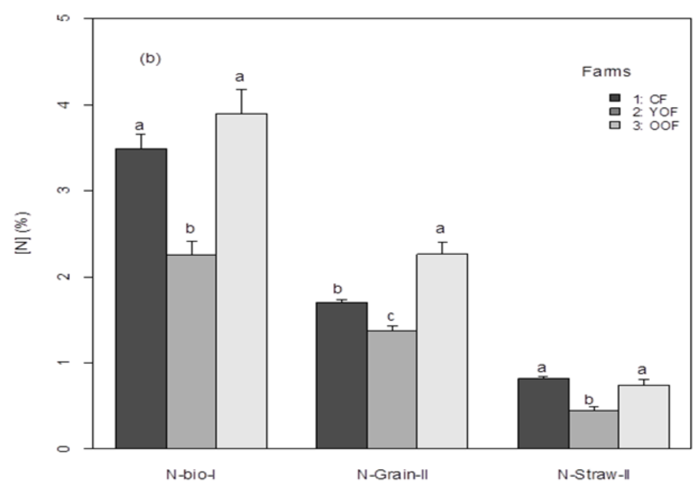




*Figure 3.* Effects of farming systems on (a) barley dry matter at stem elongation (BBCH stage 31, DM1) and ripening (BBCH 87, DM2) and (b) nitrogen concentrations at BBCH 31(N-bio-I), in harvested grain at BBCH 87 (N-Grain-II) and in straw at BBCH 87 (N-straw-II). The groups of farms compared are: conventional farms (CF), young organic farms (YOF) and old organic farms (OOF). Bars with different letters are significantly different ($P<0.05$). The error bars represent the standard error.

## 5.3 Difference in perceptions and adaptive strategies to climate change between different farm types and length of farmers' experience in farming (Paper III)

Although the farms are all located in the same geographical region with similar climate conditions, different perceptions and adaptive measures were observed amongst the farmers. Age of the farmer had an influence on the perception of climate change, as most of the farmers above 50 years of age reported experiencing effects of climate change, while only a few of the farmers younger than 50 years said the same. The key perceptions identified by the farmers were:

- *Longer and warmer growing season:* The most striking finding was the perceived change in the length and temperature of the growing season. According to the farmers, the climate is getting warmer, the spring season is arriving earlier and temperatures during winter and autumn periods are warmer than 10-15 years ago.

- *More variable and frequent extreme weather events:* Farmers reported that the frequency of extreme weather events had increased during the last 10-15 years, in the form of intense cold, dry or wet periods. Less rainfall and higher variability in length, severity or distribution of rainy and dry periods were expressed as very 'concerning' and difficult to deal with. Some farmers related these events to climate change, and these farmers tended to be those on OOF. However, YOF and conventional farmers to a larger extent considered these events to be part of 'normal' yearly variations and did not relate them to climate change.

- *More insects, pests, diseases and weeds:* Climate change was also associated with negative consequences such as increasing problems with weeds, pests and diseases. Greater occurrence of ticks (*Ixodes* sp.), horseflies and mosquitoes was reported to be problematic for livestock. Slugs (*Arion vulgaris*), insects such as leafhoppers (*Psammotettix alienus*) and spruce beetle (*Ips typographus*), weeds such as wild oats (*Avena fatua*) and fungal diseases (*e.g.* caused by *Fusarium* sp.) were all reported as increasingly problematic for crops and the farmers suggested that these problems could be the effect of climate change.

Perceiving a change in climate did not necessarily result in farmers taking adaptive measures, however. Some of the reported factors which disconnected perceptions from actions were lack of resources and knowledge, the unpredictable nature of change/variability and the intensity of risks associated with climate change.

Farmers' strategies for dealing with climate change can be grouped into proactive approaches and reactive approaches. The proactive approaches, such as crop rotation, diversification of crops and animals and introduction of new crop species, can be seen as preventative measures and many of the organic farmers surveyed tended to use this strategy. These practices were reported to be beneficial for the farm when adapting to changes in climate, but these practices were also carried out for multiple reasons. The reactive approaches included a shift in sowing and harvesting time, growing more autumn-sown crops, growing more spring-sown crops because of recent severe winter conditions, using more chemicals to deal with diseases and weeds, or growing more profitable crops such as winter wheat when the weather allows can be seen as more of an adaptive measure. There was a tendency for conventional farmers to use a more reactive approach to deal with climate change than organic farmers. The results on perceived change in climate and farmers' adaptation strategies are shown in Table 4.

Table 4. *Farmer's perceptions of climate change and their adaptive measures*

| Perceptions | Adaptive measures/strategies |
|---|---|
| Earlier start of spring season | Earlier sowing in spring and earlier harvesting. Growing/trying new summer crops with a long growing season, such as maize, sunflower |
| Higher autumn temperatures | Later sowing in autumn |
| | More flexibility in time for various farm operations |
| | Growing/trying new summer crops with a long growing season, such as maize, fava bean, sunflower |
| Milder winter temperatures | Earlier sowing in spring |
| | Growing more winter annual crops |
| Colder and longer snow cover during recent winters | Sowing spring crops in spring when autumn-sown crops fail due to weather/disease |
| | Growing more spring-sown crops (against the general trend towards more autumn-sown crops) |
| Longer and more intense dry and rainy periods | Diversification of crops and livestock and practising crop rotation to spread the risks |
| Drier summer season | Reducing the area and frequency of pea crops, as it can flower prematurely, which results in lower yield |
| Drier autumn season | Later sowing in autumn |
| Frequent precipitation during late summer | Avoiding growing peas often, as rain affects the quality of peas during harvest season |
| More unpredictable future climate | Many farmers reported it hard/impossible to deal with it, while a few claimed that crop rotation and diversification will make them more resilient to uncertain conditions by spreading risks |
| More fungal disease *e.g*. *Fusarium* sp. | More chemicals |
| More pests such as slugs, beetles, ticks, mosquitoes and horseflies | The animals (sheep and cattle) do not graze in the forest for very long |
| More weeds *e.g.* wild oats | Using more chemicals and labour to get rid of the weeds |
| Only annual variations | Some reported diversification to spread the risk, while many farmers reported it hard/impossible to deal with it |
| No change | |

## 5.4 Links between farmers' marketing channels, farming systems, farm size, and farmland biodiversity (Paper IV)

Farmers reported to sell their farm products to various buyers using both direct and indirect marketing channels. The farm products were sold to local consumers directly or indirectly, as well as to large companies and cooperatives, which have operations across Sweden or in several countries. Farmers marketing channels could be distinguished into local and distant based on the location of the consumers or buyers that were targeted. Farms were considered to use 'local marketing' when their target consumers were located within and around the Uppland province. When the products were sold to large cooperatives or companies that have operations at the country and international level, or through the open market (where crops are sold via internet bidding), it was referred as 'distant' or long marketing channels.

Based on type of marketing channels, the farms were grouped into three categories:

I Farmers selling through local marketing channels
II Farmers selling through distant marketing channels
**III** Farmers selling through a combination of local and distant marketing channels.

Farmers involved in local marketing channels often sold their produce either directly to consumers, neighbouring farmers or to local restaurants and local food co-operatives in Uppland and these farms were all OOF. Farmers selling locally tend to practise mixed farming and received income from both the livestock and cereal components. The reasons cited for these farmers selling through local marketing channels were to get a higher profit and also to offer a low price to the buyers by bypassing the middle man and transportation costs. Other reasons for selling locally were reported to be to contribute towards better social bonding with the local people and to improve the environment by reducing transport distances. These farms tended to be smaller in size in terms of area and livestock number than farms that used distant marketing strategies.

Farmers involved in distant marketing channels sold most of their produce at a predetermined (contract) price to intermediate-large cooperatives that sell their products in different countries  such as Arla (Arla Foods is a multi-national dairy co-operative), Lantmännen (a cooperative  owned by Swedish farmers, that focus on cereals for food and feed, and have activities in several European countries) and Scan (HKScan is a multi-national agro-food company that focus on slaughter houses, meat and meat products). The main reasons farmers cited for selling through contract was to get an assured price in advance, as the price fluctuate much over time. These farmers tended to specialise in either arable farming or livestock and dairy farming. These specialist farms had lower butterfly abundance and a tendency to have fewer crops, and fewer wild plant and butterfly species than farms that were orientated towards local buyers (Table 5; Figures 4). Most of the conventional farmers studied could be categorised into this group. They produced relatively few crop species and relied on external fertilisers and inputs for weed and disease control. Their crop rotation was liberal, particularly among the arable farmers, who often grew similar crops (mainly wheat and barley) year after year. Another reason mentioned by the farmers for selling through distant channels was the lack/absence of different sales channels in the region and their loyalty, contacts and ease of selling to Lantmännen. Dairy farmers seemed to be locked into only one buyer, Arla, which was said to control the milk price in the region.

Farmers that combined marketing channels mainly included farmers that practised mixed farming and most of them were farmers who had relatively recently converted to organic farming (YOF). Their farming practices differed in terms of having fewer crops in the rotation compared with the farmers that sell through local marketing channels. The farm products were sold through different channels, *e.g*. forward contract, on the open market, local-meat co-operatives (such as Upplandsbonden) and local consumers. Because of large farm size, these farms had a large surplus of crops (after on-farm consumption) and found it more convenient to sell this surplus to big companies, through contract or *via* the open market, than to several local buyers. Farmers reported this strategy of selling to both local and distant channels as a means to get a more secured and balanced price.

Table 5. *Farmers marketing channels in relation to farm size, number of livestock, plant and butterfly biodiversity (n is the number of farms)*

| Selling channel | Mean size (ha) (SE) | Mean no of livestock/ farm* (SE) | Mean no. of crop spp/ farm (SE) | Mean no. non-crop plant spp/ farm (SE) | Mean no. butterfly spp/ farm (SE) | Mean butterfly abundance/ farm (SE) |
|---|---|---|---|---|---|---|
| Local (L) (n=6) | 97 (61) | 88[a] (38) n=4 | 4.2 (0.37) | 44 (3.2) | 10.1 (1.3) | 52[c] (9.7) |
| Distant (D) (n=12) | 218 (43) | 138[b] (34) n=5 | 3.7 (0.26) | 40 (2.3) | 9.1 (0.92) | 42[d] (6.8) |
| Combination (C) (n=6) | 168 (61) | 58[a] (31) n=5 | 4.0 (0.37) | 38 (3.2) | 9.0 (1.3) | 43[c,d] (9.7) |

The values in the table are the non-transformed LS means (with SE in parenthesis). Values with different superscripts in relevant columns are significantly different in the GLM analysis ($p<0.05$).
* The means for livestock units were calculated for the farms with livestock only (cattle, sheep and pigs), and the statistical test reported in the column is for these farms; see text.

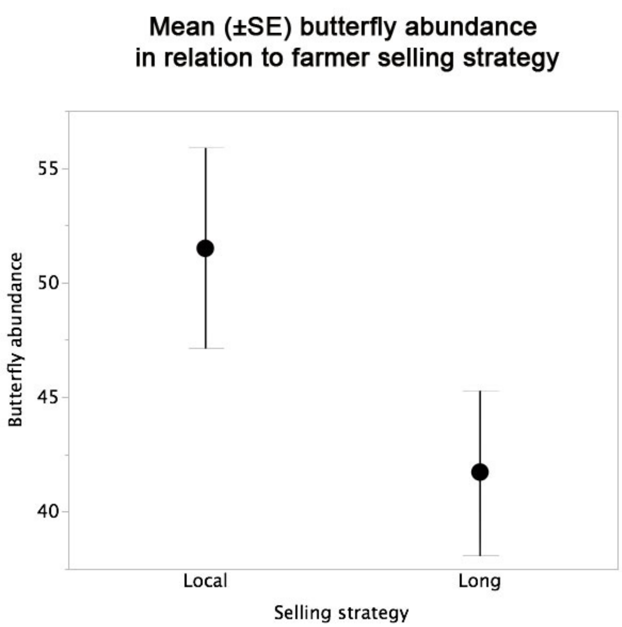



*Figure 4.* Butterfly abundance in farms with local and distant (long) marketing channels

# 6 Discussion

## 6.1 Understanding crop and farm management practices

The overall aim in this thesis was to examine farmers' crop and farm management practices and their links to farm(er) characteristics, productivity, biodiversity, marketing channels and perceptions of climate change. The results indicated that there were several overarching socio-economic and biophysical factors influencing farmers' management practices. Profit maximisation was clearly not the only motivation for farmers' management practices, as personal goals, environmental values, traditions, perceptions of and constraints in biophysical factors often outweighed the economic considerations.

The intention in this research was not to judge farmers' practices by comparing with any theories or models for best agricultural practice, but practices performed by farmers in this investigation sometimes seemed to be contrary to economic and scientific recommendations to an outsider. However, further analysis often revealed that there were logical explanations behind these practices, and discussing the reasons for their use added new dimensions to the understanding of cropping and farming systems.

An interdisciplinary approach combining bio-physical and social sciences methods (semi-structured interviews and questionnaire survey) was used in this work to assess the different farm practices in relation to crop rotation, crop yield, climate change adaptation and marketing channels. According to Duffy *et al.* (1997), although agricultural production can often be seen as a physical process, farms must not be regarded as experiments, but they are often businesses and a way of life. Thus lessons from natural science are not sufficient to understand the choices of farmers' agricultural practices, as the choices also have economic and social dimensions. The combination of different disciplines proved useful here for identifying connections between farm characteristics, management practices, marketing channels and crop performance and farmland biodiversity (Papers II and IV). Principles and rules for designing crop rotations and effects of, and adaptation to, climate change have been described and modelled by a number of authors (see list in Papers I and III), based on rationale, expert judgement and optimisation. For instance, the production of a crop or many crops in a rotation is likely to be redundant if there is no economically viable use for that crop or crops, no matter how sustainable the rotation is. In order to understand the relevance of these practices, it is important to assess crop yields, benefits in terms of weeds, disease control, soil conditions, *etc*. using agronomic sciences, determine the economic viability of the crops and also assess the practices from social sciences point of view, as farmers are likely to have differing views, goals, resources and capacities. Hence, for studying crop and farm management practices, incorporation of a systems perspective in the identification, development and evaluation of relevant improved practices with the focus on the farmer is critical, and an interdisciplinary approach is needed (Norman, 2002; Klerkx *et al*., 2012). The use of semi-structured interviews in this study helped to understand the various choices and considerations for farmers' crop and farm management practices. Semi-structured interviews were used to explore the perceptions of farmers regarding complex issues such as crop choice, perception and adaptation to climate change and marketing channels, as it enabled probing for more information and clarification of answers. Semi-structured interviews are regarded as effective and convenient means of gathering information from farmers because of their flexibility, accessibility and capability for disclosing important and often hidden facets of human behaviour (Kvale & Brinkmann, 2009; Qu & Dumay, 2011).

In this thesis quantitative statistical methods were also used to analyse the data. In Paper II where the barley crop performance was monitored weekly all through the cropping season a large data set was created which was analysed by using projection of latent structure (PLS) which is an extension of principal component analysis. The use of PLS analysis enabled to relate multiple management practices to barley performance indicators. As the focus of Paper II was on studying the different management practices and their responses, PLS analysis was used instead of ANOVA as it can handle several factors at a time and able to evaluate simultaneous effects on several performance indicators (Eriksson *et al.,* 2006). This analysis helped to determine the most relevant management practices in relation to barley performance indicators and also predicted barley performance from those management practices. The use of GLM (Poisson distributions and log-link function) in Paper II identified the links between different marketing channels and farm size, livestock number and biodiversity.

Data from both the qualitative methods (interviews and questionnaires) and quantitative methods (field experiments and species surveys) were used and analysed using various methods (structuring, condensing, categorising and interpreting the transcripts and statistics) to understand farmers' crop and farm management practices in relation to crop choice, crop yield, climate change adaptation, etc. Triangulating data from different sources allowed this study to reveal new patterns such as the relationship between crops choice, crop rotation and crop yield, marketing channels and farm size, farm biodiversity, etc., that otherwise may had not been significant when using a single discipline approach This approach of triangulating information from different sources and disciplines results in better analysis and understanding of a situation, than using a single discipline approach (Feola *et al*., 2015). The bottom line is that the each method and discipline has its merits and weaknesses in relation to the type and aim of the study; however, if the knowledge from different methods and disciplines can be combined and integrated, it can strengthen many fields of research, especially the socio-ecological systems.

## 6.2 Crop choice and crop rotation on organic farms

As Paper I showed, farmers' crop choice and crop rotation were influenced by crop price, farm(er) characteristics (goals, experience, arable farms, organic systems), social factors (such as traditions in the family farm) and biophysical factors (such as soil and climate/weather conditions). There is evidence that length of experience in organic farming had a great influence on farmers' crop choice and crop rotation strategies as several farmers practicing organic farming for more than 20 years tended to choose crop and crop rotation with focus on achieving long-term sustainability of the farms. This finding is in agreement with Darnhofer *et al.* (2005) and Flaten *et al.,* (2006) who have also showed that long-term organic farmer were willing to risk foregoing incomes for the cause of organic principles. The interview material also showed that crop choice and crop rotation in organic farming were not necessarily determined by 'the rules' of crop rotation (Castellazzi *et al*., 2009) or the principles of organic farming as laid out by IFOAM. This was the case with several arable farmers who preferred to grow more cereal crops than perennial ley, annual legumes or other break crops, using purchased fertilisers and machinery for weed control (observed in Paper I). It seems rational for arable farmers to focus on growing profitable cereal crops more frequently in their rotation, as their income comes mainly from the commercial crops they grow and not from break crops or green manures. In addition, since arable farms lack the livestock component to provide on-farm manure, other nutrient sources have to be sought. These practices are clearly within the regulations of organic farming and are important to the farmers as they are related to higher yield (confirmed in Paper II) and their marketing strategies (Paper IV). However, Seppänen and Helenius (2003) reported that crop rotations in organic farms often did not comply with the standards of organic certification and found discrepancies between the documented (to the certifying agents) and actual crop rotation practices. Such developments in organic farming with increasing reliance on external inputs and lesser emphasis on agro ecological practices have been referred to as 'conventionalisation' and are criticised as undermining the whole concept of organic farming (Buck *et al*., 1997; Allen & Kovach, 2000; Guthman, 2004; Constance *et al*., 2008). Darnhofer *et al*., (2010) argued that organic farming is also changing and adapting to a dynamic socio-economic environment, through *e.g*. an increase in farm size or by importing manures on arable farms, in order to be more competitive in terms of price and yield and thus not adhere unswervingly to the founding philosophies of the organic movement. Hauser *et al*. (2010) have also stressed the importance of self-reliance in organic systems rather than simply adopting few agronomic measures to ensure compliancy with organic standards, as a way forward for organic movement.

Nonetheless, in this thesis the reverse of 'conventionalisation' among some organic farmers has also been observed. These farmers have resorted to growing frequent cereal crops using purchased fertilisers, but encountered the problem of weeds and diseases, and then returned back to practising better designed crop rotations with break crops and legumes to reduce these problems. By setting minimum standards of allowable practices, it certainly allows a range of management practices within organic system, yet also setting the ceiling. However, the findings among some livestock farmers preferring to grow cereal crops on their land, and instead purchase feed and forage is a cause for concern and threatens to divorce organic farming from its principles.

## 6.3 Farm management practices and barley yield

Adoption of different farm and crop management practices by individuals and by group of farmers was clearly reflected in their crop yield (Paper II). It was shown in Paper I that the OOF mainly used internal resources such as leys and break crops to maintain soil fertility, weed and disease control, while several arable YOFs grew few cereal crops species, focused on using external inputs and machineries and had certain characteristics of conventional farming systems. Management practices on conventional farms can go even wider with the possibility of use of chemical fertilisers and herbicides. Paper II shows that these differences in the management practices and inputs influenced barley performance with higher barley grain yield observed in conventional farms than in organic farms. Even with organic farms, differences in yield could be observed between farms attributing to their different management practices. The higher barley yield in conventional farms and in some organic farms were related to the use of fertilisers and manures, the amount of fertilisers applied, effective weed and pests control and timely application and availability of nutrients to the crops. Kirchmann *et al*. (2007) reported the inverse relationship between weed population and yield as weeds compete with crops for nutrients. Clark *et al*. (1999) also attributed the poor mineralisation capacity of organic manures for low crop yield in organic farms compared to mineral fertilisers, which are often applied in conventional systems.

Although, it was observed that frequent application of organic fertilisers and mechanical weeding can improve barley yield in organic systems, these practices might involve greater cost for inputs and machinery. However, no economic evaluation was done on the study farms. In addition, such cropping practice dominated by few cereal crops can have implications facing climate change, in particular during years experiencing weather extremes (Paper III). Furthermore, Delbridge *et al.* (2013) found that that higher yield in conventional farms results from higher management costs, and because of the often lower management costs in organic farms, in combination with higher price for the products, it can outperform conventional farms in terms of profitability. Despite, the lower barley yield in organic farms that practiced crop rotations compared to conventional farms that grew fewer crops with external inputs, the use of crop rotations is necessary in organic systems as it offer multiple benefits such as weed and disease control and maintained soil fertility, as demonstrated in Paper I and elsewhere (Bertsen *et al*., 2006; Papadopoulos *et al*., 2006; Castellazzi *et al*., 2008). As shown in Paper III, practising crop rotation and diversified farming (with diverse crops and livestock) also helps in coping with weather variability and adaptation to climate change.

## 6.4 Farmers' perceptions and adaptation to climate change

The findings in this thesis also suggest that farmers' experience (age of farmer, experience of climate change and time since conversion to organic farming) has a great influence on their perceptions of climate change and, in particular, of recent weather extremes (Paper III). Compared with younger farmers, a greater number of older farmers (above 50 years of age) reported having observed climate change and also associated extreme weather events with climate change (which they claim have become more frequent in recent years). This could be related to their long farming experience and their accumulated knowledge of the environment, including changes in climate conditions. On the other hand, the lower perception of climate change by young farmers (below 50 years) and their tendency to consider the weather extremes they experienced as normal yearly variations may be attributed to shorter-term exposure to climate conditions and less experience of dealing with changing farming conditions. Lower perception of climate change due to shorter experience of farming among young farmers agrees with findings by Deressa *et al*. (2009) and Juana *et al*. (2013). However, Islam *et al*. (2013) did not find any relationship between farmers' age and the perception of climate change, but reported that farmers who have direct personal experiences with the adverse effects of climate change stated to perceive climate change. However, this personal experience (reported by Islam et al., 2013) can be closely related to the age, as old farmers are likely to have faced more encounters than young farmers and also be able to relate to their longer knowledge/experience of weather variations. This is in line with 'Theory of Learning' (Chawla, 1999) according to which, the development of peoples' perceptions and attitudes are influenced by formal education, as well as people's direct personal experience. However, Poortinga *et al*. (2011) reported the opposite, *i.e.* weaker understanding and lower perception of climate change among old age individuals than young individuals among the British public. Those authors attributed this to high awareness of climate change among young individuals due to the inclusion of environmental education in the school curriculum, and the recognition and debates on climate change which are of recent origin. The reasons for the difference with the findings in this thesis could be the inclusion of young individuals (from 15 years onwards) in Poortiga *et al*. (2013) who are more aware of environmental issues and climate change from the media and school curriculum. While in this study, all the farmers were above 30 years of age and they are likely to have different level of influence from the media as well as from the old school curriculum about climate change and environmental science.

The difference in perception of climate change among farmers in this thesis was reflected in how they dealt with climate change and weather extremes. The use of strategic long-term approaches such as crop rotation and diversified farming by several organic farmers, especially by OOFs, reported in Paper I and II, may have helped these farmers when dealing with climate change and weather extremes. Bradshaw *et al.* (2004) and Furman *et al.* (2011) also report use of crop diversification as the most important strategy for climate change adaptation among organic farmers in Canada and USA, respectively. According to Mccan *et al*. (1997) and Darnhofer *et al.* (2005), practices such as crop rotation and diversification among organic farmers can potentially help them cope with climate change, but these practices are employed for multiple purposes, with environmental sustainability being only one of the important reasons. The results in this thesis further confirmed that the long-term approaches adopted by several organic farmers were not primarily intended for climate change and weather extreme adaptation, but for dealing with weeds, diseases and soil infertility, providing better marketing opportunities and greater biodiversity, as shown in Papers I, III and IV.

The use of 'adaptive measures', such as a shift in sowing and harvesting time, growing more autumn-sown crops, using more chemicals to deal with weeds, pests and diseases, or growing more profitable crops when the weather allows, to deal with climate change and weather variability were common among the conventional farmers surveyed. This approach is more common in conventional agriculture as they have more solutions and better possibilities (external inputs) to use adaptive measures than organic agriculture (Watson *et al*., 2002; Francis & Porter, 2011). However, as evident from Paper I, these practices are also becoming more common in organic agriculture with the development of improved weed control technologies, fertilisers sourced from livestock, and natural insecticides and pesticides.

Perception of a climate change risk did not necessarily result in adaptation measures being taken by some of the farmers surveyed here. This passivity among farmers differs from the situation reported in other studies (O'Connor *et al*., 1999; Mertz *et al*., 2009; Mubaya *et al*., 2012; Arbuckle *et al*., 2015), which indicated that individuals are likely to adopt adaptation measures to climate change when they understand the consequences of inaction. However, Grothmann and Patt (2005) claim that adaptation is not only determined by risk perception and the farmer's abilities, but also by socio-economic, cognitive and various other factors. Deressa *et al*. (2009) included lack of information on adaptation methods as another factor responsible for lack of action. Some farmers in this thesis did not take adaptive measures, despite perceiving the risk of climate change on their farms, as they did not have resources such as irrigation or drainage systems to deal with droughts and floods, knowledge on how to deal with climate extremes and also uncertainty of weather extremes, that was difficult to plan for.

## 6.5 Farmers' marketing channels and their links to farm characteristics and farm biodiversity

Farmers' marketing channels were found to have connections with cropping system, farm size (area and number of livestock), farm type and butterfly abundance (Paper IV). The relationship between these factors is complex and it is often difficult to identify what is the 'cause' and what is the 'effect'. This is the reason why the term 'link' has been frequently used in Paper IV. For example, it is difficult to state whether small scale (area and livestock) necessitated the farmers to sell their products in local market to get premiums, or, the low demand from the local market was more suitable for small scale farmers to sell in local markets than large scale farmers. However, sometimes there were indications of cause-effect relationship between various factors based on strong evidence from the interviewed farmers and support from relevant literature. The data revealed that farmers who sold their products in local markets tended to have smaller-sized farms and grew more diverse crops than farmers who sold their products through distant marketing channels. According to Smithers *et al*. (2008), Navarette (2009) and Le Roux *et al*. (2010), farms that are geared towards local marketing channels tend to practise organic farming and produce a range of crops and livestock from small-sized farms. This diversification of crops and livestock, despite resulting in lower yield (observed in Paper II), was practiced by several organic farmers for improving the environment, reducing external inputs such as organic fertilisers and mechanical weed control (Paper I), and also to be resilient to climate change and weather extremes (Paper III). The reason for farmers to grow diverse crops seems to be related to local consumers' demand, as pointed out by several authors (Nilsson, 2009; Conner *et al*., 2010; Olsson, 2015). Those studies claim that consumers who buy food from local markets are more conscious of the environment and of the health benefits of organically produced foods, and have a greater desire to stay away from mainstream food, compared with consumers who buy from retail supermarkets. The reported link between local marketing strategies and consumer behaviour is credible. However, the situation can also be interpreted from another angle, in that the small-scale nature of the farms, in this case, seemed to necessitate use of organic farming practices to produce diverse products, in order to avail higher price opportunities for organic produce, and also to obtain a range of products in small quantities which can be sold during most of the year (year-round income). On the other hand, the reasons for some large farms producing diverse products and selling to local markets were reported for enhancing ecosystem services, spreading out the risk in the event of sudden calamities (such as weather extremes and price fluctuations), the convenience of selling (small quantities) to local consumers directly, and for better social bonding. Several farmers were unable to sell their products to local markets (in order to get premium price) as the local market could not accommodate large quantities at the same time (such as a batch of livestock ready for slaughter at the same time). However, if local markets are scaled up, there is a risk of difficulty in differentiating the mainstream food systems from the local/alternative systems and it might end up as the same debate as conventionalisation of organic agriculture which is discussed in Paper I.

The trend of low farm biodiversity found on farms that sell through distant marketing channels could be attributed to the specialist nature of farming to produce few crop varieties and use of pesticides for weed and disease control, as they were mostly conventional farms. Jonason *et al*. (2011) showed that the abundance of butterfly and plant species increases with time since conversion to organic farming and that biodiversity is lower on conventional farms than on organic farms. The results in this thesis confirm the link between farmland biodiversity and marketing channels.

## 6.6 Links between farm characteristics, productivity, perceptions of climate change, marketing channels and biodiversity

An important finding of this thesis was the identification of links between the different objectives: farmers' crop choice and rotation, crop yield, climate change adaptation, marketing channels and farm biodiversity. Studying various farm types within the organic and conventional systems, enabled to identify and discuss a range of management practices practiced by both the organic and conventional farmers and highlighted the nuances between the two systems. This information further helped in identifying links between farm(er) characteristics and their crop and farm management practices. This thesis brings together several important factors which influences farmers' crop and farm management practices into one study and shows how they are interlinked. For instance, practicing crop rotation or growing diverse crops by several organic farmers, was primarily aimed for improving soil conditions and controlling of weeds and diseases (Paper I), but these practices were also reported as strategies to spread out the risk during adverse weather conditions (Paper III). Furthermore, the same practices were found to assist the farmers in availing local marketing, price premiums and farm biodiversity (Paper IV). These practices could be considered as strategic long-term practices to improve the economic and environmental sustainability of the farm and social bonding in the long run, though it might have also born out of necessity as organic farmers do not have as many means as the conventional farmers to offer quick solutions (use of chemical fertilisers, herbicides and pesticides) to address important farm problems. Koesling *et al.* (2004) and Flaten *et al.* (2005) reported that the organic farmers in Norway also used more preventive approach such as diversification as they were less risk-averse than the conventional farmers. However, the reasons for practicing crop rotations and diversification could also be attributed to small farm size and low yield. As it was observed in Paper II that farmers that practice crop rotation and diversification were not only smaller in size, but their crop yield was also significantly lower than the large and (more) specialized farms. Small farms need to earn more profit per unit product or farm area to compensate for the lower yield, and one strategy is to produce organically (to receive premium price) and sell to local consumers directly. This strategy had positive influence on farm biodiversity (Paper IV) although it might not have been their sole intention. However, the higher biodiversity observed in farms that sell through local marketing channels further links back to the results of Paper I, where several OOfs claimed that their crop choice and crop rotation was to enhance biodiversity and ecosystem services in their farms.

# 7 Conclusions and recommendations

The thesis set out to understand farmers' crop and farm management practices and their links to farm(er) characteristics, productivity, biodiversity, marketing channels and perceptions of climate change.

The combination of different methods and approaches unravelled some of the complex set of factors (such as age, experience, farming goals) that influenced farmers' crop and farm management practices and helped to achieve a better understanding of their interrelationships. However, some of these factors were also found to be intertwined and it was difficult to establish cause-effect relationships. Based on the results, it was possible to draw the following main conclusions:

- The crop rotation strategies of organic farmers with longer experience of the organic practice (OOFs) are strongly influenced by organic principles and they generally have diverse crops and incorporate ley crops in their rotations. Moreover, their crop rotations are flexible, to allow them to adapt to changing conditions.

- Young organic farmers on the other hand either grew few crop species in rotation to control weeds and diseases, or choose crops without an intended crop rotation (liberal) mainly for better economic reasons. The tendency of some organic farmers (both arable and livestock) to overlook the importance of diversified crop sequence (including ley) in order to secure short-term economic benefits by growing frequent cereal crops, may require farmers to invest in technology for weed control and may cause them to become more reliant on external inputs.

- The key management practices which were found to influence barley performance in organic farms were the use of leys and cereals as preceding crops, proportion of rotational leys, proportion of arable land, presence of pasture on farm, percentage weed cover, application technique of organic fertilisers and straw and crop residues left on the field. In conventional farms, in addition to the above factors, the use of chemical fertiliser, herbicides and pesticides influenced barley performance.

- Higher perception of climate change was observed among old age farmers (>50 years) than young farmers (< 50 years) indicating that the length of experience and exposure to annual weather variations and trends affecting farming, influences farmers' perceptions of climate change. Adopting proactive long-term practices such as crop rotations with diverse crops and having a livestock component on the farm can make farms more resilient to the negative effects of climate change and weather variability. There are certain opportunities for farmers in the study area to benefit from climate change as reflected in a longer growing season, such as achieving better crop yield and introduction of new (profitable) crops.

- An association was demonstrated between use of local marketing channels and small farm size (area and livestock), OOFs, high biodiversity and diverse farm products. Distant and mixed marketing channels were found to be more associated with large farm size, few specialist products in large volumes, selling to retail companies few times a year and lower farmland biodiversity. Local marketing appeared to have the potential to offer better economic and other social and environmental benefits, but this marketing channel seems to be more relevant for small-scale farmers, as the local markets are not accustomed to accommodating large quantities at a given time, despite the farmers perceiving a local demand for their products.

This thesis illustrates that weeds and soil fertility management are major problems for organic farmers, despite practicing crop rotation and soil fertility measures (using leys and legumes). Research is needed to identify and develop more effective measures to address these issues than the existing measures in the study region (Uppland, Sweden). The significantly lower barley yield in organic farms compared to conventional farms needs to be looked into in order to address the bottlenecks in organic management practices. However, new methods to improve yield and to address the need for more efficient weed management in organic systems should also be sustainable and meet the agro-ecological and environmental requirements. It is a great challenge to address the productivity issues in organic agriculture without detaching from its core values and principles which consumers associate with organic production.

With regard to conventional farms, research is needed on improving the biodiversity, social image and direct marketing opportunities. Finding more ways to sell to local consumer directly while at the same time distinguishing itself from mainstream marketing and food systems to get a premium price for 'locally produced' should be searched for.

In addition to these specific findings, the thesis also identifies and addresses a number of interrelated questions at the interface between farmer motivations and perceptions, crop and farm management and experience of farmers, choice of marketing channels and biodiversity in the Uppland province using interdisciplinary approach. An increased focus on integrating knowledges from different disciplines to understand farmers' management practices and their implications can help in addressing relevant issues faced by farmers and the consumers, and also in finding solutions that are appropriate to specific farms or group of farmers in a region. Such specific and in-depth information can be useful for guiding regional and local policy development and can assist farm advisors in providing relevant information and training to improve the economic, social and environmental conditions of farmers. In order to understand and identify additional concerns and opportunities, similar studies should be carried out in different regions and scaled up, to cover broader and diverse contexts.

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