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Factors influencing crop rotation strategies on organic farms with different time periods since conversion to organic production

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Abstract

Productive crop rotations are central to the success of organic production systems. The selection and sequence of crops are determined by a combination of agronomic and economic factors as well as the principles and standards of organic farming. Semi-structured interviews were conducted with sixteen organic farmers in Central-east Sweden to explore the factors that influence the design of crop rotations and the trade-offs between these factors, taking into account the length of time since conversion to organic production.

We discerned three crop rotation strategies: strict, flexible and liberal, based on how crop(s) are repeated over time. A major trade-off for arable farmers was between perennial leys to provide nitrogen and control weeds, and the use of more inputs such as purchased nutrients and mechanical weed control to allow continuous cereal production. Critical considerations for livestock farmers were the length of ley for feed production and weed control, cost of re-seeding leys and decisions about whether to grow crops to feed animals or cereals to sell. Farmers practicing organic for a long time (more than 10 years) often had flexible rotations to adapt to changing conditions, but they generally included leys and a selection of annual crops in line with the principles of crop rotation and organic farming. Recently converted organic farmers usually concentrated on controlling weeds and producing sufficient livestock feed by following strict crop rotations. We conclude that farm type and experience strongly influenced rotation strategies and that weed management and market prices were the most important influences.

Keywords: crop rotation strategies, decision, organic farming, semi-structured interviews, time since conversion, trade-off

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Introduction

Crop rotation is the sequence of crops on the same land in sequential seasons (Bullock 1992) and implies that crops generally follow a pre-determined order. Crop rotation is determined by decisions made by farmers on what type of crops to grow in the current and coming growing seasons. The choice of crops to include in a crop rotation can influence soil fertility and nutrient cycling, risks of infestation by weeds, pests and diseases, nutrient demand, crop diversity, and economic risk management (Karlen et al. 1994; Gerhardt 1997; Bertsen et al. 2006; Papadopoulos et al. 2006; Moncada & Sheaffer 2010). Crop rotation is of particular importance in organic farming, compared to conventional farming, because of the restrictions on the use of easily soluble mineral fertilisers and the prohibition of synthetic chemicals to control weeds, pests and diseases. Hence, Article 5 of 834/2007 of European Union's principle applicable to organic farming (EU 2007) emphasises the adoption of appropriate crop rotations with diverse crops in order to maintain/improve plant and soil health, and also to minimise the dependence on external inputs as far as possible. A wider description of the core values and principles of organic farming was laid out by IFOAM (2005) which forms the basis for the definitions.

In practice, the crop sequence often changes over time as an adaptation to prevailing conditions, preferences and knowledge and the different trade-offs which farmers have to consider when choosing crops. Dury et al. (2013) reported that the cropping plan on a farm does not emerge from a single decision but from a dynamic decision-making process, which among other things incorporates unanticipated situations such as lack of availability of particular seeds, weather conditions and market opportunities. Since many factors influence crop choice in a rotation, it is not always practical for crops to follow each other in strict, repetitive cycles. This is particularly true on arable farms that depend on cash crops rather than growing crops for livestock feed. Therefore, it is often more relevant in practice to discuss crop sequences rather than crop rotations.

Castellazzi et al. (2008) identified several important factors to consider when designing well-functioning crop rotations, and grouped them into four main rules. According to the first rule, there should be a minimum return time period of the same crop in the rotation, or in some cases, the maximum period of growing the same crop, in order to break the cycle of the build-up of pests, weeds and diseases. The second rule states that crop rotations should be planned to optimise the benefits from crop succession. The benefits could arise from increased nitrogen supply, soil organic matter or water availability, improvements in soil structure, and decrease in pests, diseases and weed competition. The third rule relates to planning the timing of operations within a year to allow crops to follow each other without long gaps. The fourth rule relates to diversity of crops in space and time in order to spread the risk of total crop failure and economic loss, and also balance the distribution of work and the use of machinery and labour.

Decisions of individual organic farmers on crop choice may not always address the rules of crop rotations or the principles of organic agriculture, as farmers also have to consider many practical aspects. Several published studies on development of crop sequence/rotation are generic and based on decision support and modelling tools, e.g. Bachinger and Zander (2007), Power et al. (2011). These studies use mathematical optimisation techniques to generate rotations to assist in agricultural production planning. Other studies describe the different phases and processes which lead/link to the decision making process (Aubry et al. 1998; Öhlmer et al. 1998; Dury et al. 2013). The above tools help in designing crop rotations based on generic conditions and assumptions, but they do not reflect the individual farmer’s experiences, motivations, arguments and uniqueness in their situations and decisions, as they are based on optimisation and prediction approaches. Although, the general needs and requirements of different farm types vary, individual farmers will respond to external factors, in addition to the requirement of their farm types. A report from the European Commission (2010) lists several factors such as climate, soil quality, water availability, local market opportunities, farm resources and policies, the education level of farmers, tradition on the farm or in the surrounding farming community, etc., which could influence the choice of crop rotations. This report did not explore how decisions are taken by individual farmers when faced with different constraints and trade-offs. The rationale behind their choices could reveal the different constraints and opportunities associated with various crops and crop rotations in a particular farm or farm type. To our knowledge, there are no published studies which critically look into the rationale of organic farmers when determining their crop rotations.

We expect the longer-term organic farmers to be more knowledgeable about crop rotations since they have more varied and longer experience in organic farming systems than the recently converted organic farmers. This study seeks to explore crop rotations practiced by farmers with varying experiences and farm types, identify the 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. We do this by analysing qualitative data from semi-structured interviews with 16 organic farmers in the Uppland Province, Sweden. A qualitative approach was chosen based on the premise that farmers' goals and ideologies influence their decisions on crop rotations. The semi-structured interviews allowed the farmers as well as the interviewers to raise doubtful issues and questions and discuss further to get more meaningful answers.

Materials and methods

Studied farms

The study was carried out in the Province of Uppland located in Central-east Sweden. Uppland has a relatively flat topography with the highest elevation point 117 m above sea level. Agriculture is characterised by cereal farming on the open plains and more livestock and mixed farming with a high percentage of rotational or improved grassland (grass-clover ley) in the mixed and more forested areas. Rotational grass-clover leys (a mixture of clover and grass species) often including red clover (*Trifolium pretense*, L.), white clover (*Trifolium repens*, L.), timothy (*Phleum pretense*, L.) and meadow fescue (*Festuca pratensis*, L.) cover about 40% of the arable land while winter wheat (*Triticum aestivum*, L.) and spring barley (*Hordeum vulgare*, L.) are each grown on about 15% of the arable land (Swedish Board of Agriculture 2011).

We conducted the study with 16 organic farm owners with diverse farm types and time periods since conversion to organic farming, in order to include farmers with a variety of objectives and with different levels of experience in organic farming. The farms have been certified organic for between 2 and 25 years with the Swedish organic trademark, KRAV. These farms were originally selected to represent organic farms with different periods since conversion and have been used in several studies of biodiversity and ecosystem services (Jonason et al. 2011; Jonason et al. 2012). The importance of landscape was considered in the original study by selecting the farms along a gradient of landscape heterogeneity. The farms have been grouped according to their main farming activity into arable, dairy, beef/sheep, pig and mixed livestock farms.

Interview methods and analysis

We used semi-structured interviews, which are widely employed to gain a good understanding of the attitudes and decisions of farmers towards different management options (Longhurst 2003). The interviews were carried out on the farms in spring 2011. A list of key words which could describe the essential information relating to crop choice and crop rotation was prepared and tested with one farmer (not within the group of farmers interviewed), and necessary changes were made and then used for conducting the 16 interviews (Table 1). Using the list of key words, farmers were asked open-ended questions, with probing whenever necessary to obtain robust information required for the study. The interviews lasted between one and three hours. Several farmers showed us around their fields and livestock units during and after the interviews and these also provided opportunities to observe the management procedures and also to gain additional information. All interviews were recorded and transcribed. We used the software 'Atlas.ti' (ATLAS.ti GmbH, Germany) to help condense structure and categorise the different statements of the transcribed information. This approach is recommended by Kvale (1996). All the statements relating to crop rotations and their rationale were coded into categories and key words.

[Table 1 near here]

Results and discussion

General farm characteristics and crop rotation strategies are summarised in Table 2. The different crop rotations practiced by the farmers and their rationales are discussed within different farm groups in the following sub-sections.

Arable farmers

The arable farmers interviewed mainly depended on cereals, mostly winter wheat, for their income. Most farmers also included perennial clover and grass crops used as a green manure (in the following text referred to as 'ley') in their crop rotations. The ley crops were under-sown in annual cereal crops and remained for at least one more year during which they were cut regularly to control weeds, and also in some cases to sell hay or silage to neighbouring farms. In the year of ley incorporation, a short period of black fallow (repeated tillage to control weeds) was often applied before sowing winter wheat benefitting from the pre-crop effect of the ley. Most farmers also included a grain legume in the rotation, i.e. field beans (*Vicia faba,* L.) or peas (*Pisum sativum,* L.), in pure stand or in mixtures with oats (*Avena sativa,* L.).

Most of the arable farmers reported that they were growing cereals as frequently as possible in the rotation and avoided the use of break crops, such as legumes. With one exception, they did not follow a planned crop rotation, but adjusted their crop choice according to the prevailing situation. A farmer who had managed his farm organically for more than 20 years (Farmer 1) remarked:

"I don't follow a planned rotation as I might have to change crops according to market price. I mostly grow wheat after ley. But from this year onwards; I applied Biofer (meat and bone meal fertiliser, mainly from conventional sources) to my cereals and avoided growing ley and legumes. I cannot have peas and beans more than every sixth year in the rotation because of pests and diseases, and since I don't have animals to eat them, they can easily be replaced with cereals".

His statement indicated that he was not happy with the practice of growing leys and annual legumes as he didn't find them useful. However, frequent cultivation of cereal crops could increase damage caused by pest and diseases and risk to reduce grain yields compared to more diverse crop rotation. Recent research investigating effects of preceding crops using a wide range of experiments from all over the world shows that wheat grown after a break crop can be expected to yield between 0.5 and 1.2 t ha^{-1} more than wheat after wheat (Angus et al. 2015). Management of nutrient supply was reported to be one of the greatest challenges for arable (stockless) organic farmers as leys are of little economic benefit to them, and also do not increase the total supply of nutrients other than nitrogen through biological nitrogen fixation by legumes such as clover (Watson et al. 2002). Thus, the present farmer substituted the perennial ley, which produces many system benefits, such as break crop effects on weeds, pests, diseases as well as reducing external nitrogen input, with 'Biofer' fertiliser that provide a range of nutrients but not the other benefits. Farmers appear to see a choice between growing leys and annual legumes in the rotation on one hand, and applying 'Biofer' to have more land available for cereal, on the other hand. The use of 'Biofer' to grow more cereal crops can be seen as a shift towards a more 'conventional' farming approach, in terms of the farmer's reliance on off-farm nutrient inputs and more specialisation in the system. This approach deviates from the rules of crop rotation as the same/similar crops are grown consecutively for several years which might result in the build- up of pests, weeds and diseases. In addition, the dependence on external fertiliser and less crop diversity in the farm does not seem to fit with the principles of organic agriculture to utilise diversity and to use legumes to provide nitrogen rather than purchasing external inputs. Replacing nitrogen fixing and soil improving crops, such as grass-clover ley, with inputs from outside the system that are derived from e.g. livestock raised conventionally were widely used in organic farms in Denmark (Oelofse et al. 2013). Several other studies have also reported that many organic farmers are moving towards 'conventionalisation' of their organic farms in terms of more farm specialisation, larger farms and intensive use of external fertilisers and less regard for the principles of organic farming (de Wit & Verhood, 2007; Darnhofer et al. 2010; Oelofse et al. 2011; Nowak et al. 2013). Another farmer who has been organic for the last 12 years (Farmer 3) already followed a more conventional approach similar to that of Farmer 1. Farmer 3 did not plan his crop rotation in advance, and grew crops according to the market price. His goal was intensive production reliant on purchased fertilisers. He said:

"*My crop sequence is almost free. I choose crops which give the most profit at the moment. So I have a very intensive organic system. I buy organic fertilisers such as Biofer and Biovenass (a by-product from commercial yeast production) for my crops to produce more wheat instead of growing ley or peas.*"

The above quote indicates that the current market price was the most decisive factor for him when choosing crops in the sequence. He was the only farmer who did not grow any ley and he also reported managing the weeds successfully using modern machines and without any break crops in his cereal rotation. The farmer, however, reported growing field beans in some years, if the price was high enough.

The same farmer further commented:

"*I think the first farmers who started organic farming were idealists. But now it is not like that. I think it is more that we want to have the same output as conventional farms.*"

His comment indicates that he thinks that there is a trend towards more market oriented farming practices amongst the recent organic adopters and that he thinks it is possible to achieve the same yields as in conventional agriculture. He explained that his generation of organic farmers aims at increasing productivity by managing the farm intensively using external fertilisers and modern machinery to control weeds. One farmer (Farmer 4) who had tried to grow mostly cereals in the crop rotation describes how that led to problems with weeds. Because of these problems, the farmer decided to go back to a planned crop rotation with legumes and break crops in order to find solutions to the problems. He made the following comment on his earlier crop rotation strategy:

"Before developing this crop rotation three years ago, I had quite a free crop rotation. It was much more depending on the market. The price of different cereals was a bit uncertain at that time, so you never really knew what to sow. May be the free crop rotation caused the big thistle problem that I have experienced. I was too eager to grow cereals, not really thinking about the consequences."

The quote reveals how this farmer shifted his focus from a profit-oriented crop rotation to a more ecological farming based on the rules and principles of crop rotations and organic agriculture, because of problem with creeping thistle (*Cirsium arvense* L.). This farmer has been practicing organic farming for 12 years and grew as much cereal (mainly winter wheat) as possible to maximise returns until three years ago. The new rotation includes leys for one or two years to control perennial weeds followed by two years of winter wheat. Thus, the farmer made the choice to grow wheat with leys in the rotation to avoid weeds, rather than growing more crops of wheat at low yield due to e.g. weed problems. During the interview, the farmer also highlighted that his crop rotation with a ley crop in the sequence offers other benefits, such as building up the nutrient stock for the winter wheat crop and improving the soil structure.

A farmer managing his farm organically for the last 10 years (Farmer 5) did not follow a planned crop rotation. He was flexible in the choice of crops species in the rotation. The rationale for his decision was to be able to adapt to variable conditions such as disruptions due to pests, weather, etc.

Crop rotation strategy of a farmer who inherited the farm from his grandfather and has been managing his farm organically for 18 years (Farmer 2) was based mainly on tradition and farming experience. Although the livestock component was abandoned 16 years ago in the farm, he reported following the same crop rotation as in the last 70 years as he claims to have good knowledge of this rotation. He remarked:

"I have not changed the crop rotation that my grandfather used since the 1940s, because I know it very well and this rotation controls the weeds. I still grow ley even though I do not have cows now, as I trust this rotation. I can sell some of the forage to the neighbours, though not at the same good price as the wheat."

His statement reflects the importance of experience when deciding crop choice and rotation. The farmer chose to trust the well tested crop rotation which was designed with proper break crops, rather than changing to a new one, which could potentially be more profitable. During the interview, the farmer also mentioned that he thinks that the inclusion of ley in the rotation helps to improve the soil. Rotational leys are known to increase yields of the other crops in the rotation (Johnston et al. 1994; Persson et al. 2008)

In summary, lack of direct economic benefits of growing leys was the reason why several of the arable farmers do not to grow leys and diverge away from the rules of crop rotation and principles of organic agriculture. Instead, some of the farmers follow a market oriented crop rotation practice focused on growing cereals with the intensive use of machines and external fertilisers. The two most important trade-offs mentioned were, firstly, the use of external fertilisers and intensive control of weeds to grow more cash crops, and secondly, the use of legume crops and crop diversity in rotation to support soil fertility and for controlling weeds and diseases. Moreover, the farmers who followed a planned crop rotation seemed to be more driven by organic principles than the more commercially oriented farmers with more flexible and liberal crop rotation strategies.

Dairy farmers

The typical crop rotation reported by the dairy farmers was two or three years of ley followed by two years of cereals. The first year of cereal was always wheat (winter wheat preferred over spring wheat), while the second year could be wheat, barley or oats, e.g.:

> Ley 1- Ley 2-Winter wheat- Wheat/Barley/Oats-peas under sown with a clover-grass mixture

It is evident from the general crop rotation (above), that the need for feed leads the dairy farmers to incorporate more ley crops in their rotations than the arable farmers. According to a farmer who had been practicing certified organic farming for 25 years (Farmer 6), he followed a planned crop rotation in order to produce sufficient feed for the livestock, and also some cereals for direct cash income. He included oats in the rotation even if he had more use for barley and wheat as feed, because he considered oats to be more competitive towards weeds, and easier to manage than higher value crops such as wheat and barley. Oats is considered an important crop in areas with short growing seasons and long day-length regimes and hence is well suited to the study area (Buerstmayer et al. 2007). Oats are particularly suitable in organic farming where the availability of nitrogen is generally lower and the need for competitive crops is larger than in conventional systems. He also wanted to have great crop diversity to spread risks and because it was his experience that more crop diversity leads to fewer problems with weeds, pests and diseases.

Furthermore, his crop rotation was aimed at managing weeds and he experimented with different crop sequences to develop his farm management. He remarked the following about his crop rotation for controlling the weeds:

"We had problem with weeds. We have tried rotations with 3 or 4 years of ley, but then there was the problem of the perennial weed, couch grass. The couch grass spread to the barley. We also got less material for silage. So now, with two years of ley, there are fewer weeds and we could get good yields. Of course it is also expensive to re-seed the ley every 2 years, but it is better than having weeds."

His statement reflects the choice between efficient weed control and the costs of frequent re-seeding of the ley crop. According to his experience, two-year leys were optimal for long term yields considering the need for keeping weeds, i.e. couch grass (*Elymus repens, L.*), under control in the rotation. Several other perennial weeds, particularly stationary ones such as dandelion (*Taraxacum* spp.), thrive in leys, but are not very competitive in annual crops. The control of couch grass depends mainly on having competitive crops and cultivating the soil between crops (Håkansson 2003). This also shows that proper planning and length of period of certain crops in a rotation can prevent propagation of particular problematic weed species.

According to a farmer rearing 90 dairy cows and practicing organic farming for 13 years (Farmer 7), the rationale for the crop rotation was to meet the feed requirement of the dairy cows. He said the following about his crop rotation:

"*I follow a planned crop rotation because I am compelled to do it. I need a lot of grass-clover ley to produce forage for the animals and then, peas and barley mixture as protein supplement for the cows. The good thing is also that I do not need to buy fertilisers, and the rotation is good for the soil. Thistles are controlled in this rotation if I cut the leys 3 times a year.*"

The focus on producing feed for the animals is in line with Flaten et al. (2005) who reported that the main cropping goal of Norwegian dairy farmers was to produce sufficient feed for the livestock as organic livestock feed was reported to be expensive. Producing livestock feed on farm also fits within the guidance of organic regulations for the use of locally produced feed.

The aim of a farmer practicing certified organic farming for 12 years (Farmer 8) was to adapt his crop rotation according to the market price of cereals. He often chose to grow wheat instead of protein rich crops such as peas and beans for his livestock. Thus, this farmer could consider replacing feed crops with profitable cash crops and instead purchase the feed. The crop rotation strategy of a recently converted organic farmer (Farmer 9) was to avoid weeds and diseases in the crops. The farmer developed a crop rotation plan when he became a certified organic farmer which included two years of ley followed by one year of winter wheat and then a fourth year with winter wheat or *Triticale*. His strategy was to buy the protein fodder from other farmers, because he considered the annual legumes difficult to grow as they are susceptible to adverse weather conditions, pests and diseases.

To summarise, most dairy farmers followed the rules of crop rotation by having diverse crops and leys to control weeds, pests and diseases. However, the strategy of a few of the farmers to rely on external feed by growing more cereals is not in line with the principles of organic agriculture. The most important trade-off observed amongst dairy farmers in regard to their crop rotation was between growing sufficient feed for the livestock, and growing cereal crops for cash. Several farmers who were flexible in their crop rotation tended to focus on cereal cash crops and thus had a higher dependence on external sources for feed than other organic dairy farmers interviewed. It appears that it was more important for the long term organic farmers in the study to be self-sufficient in feed than it was for the recently converted farmers, who were more willing to purchase feed.

Beef and sheep farmers

The crop rotation strategies of beef cattle/sheep farmers were very variable, but it was quite common to have three years of ley and two years of cereals (winter wheat or spring barley). Some farmers also had peas or beans after the first or second year of cereals and then added another cereal crop at the end of the rotation. A typical rotation was:

Ley 1- Ley 2- Ley 3- Wheat /Barley- Wheat/Oat under sown with grass-clover

Similar to many dairy farmers, the objective of the crop rotation for Farmer 13 was to follow a planned rotation in order to produce sufficient feed for the livestock as well as cereals for direct cash income. Despite mentioning the problem of thistles in wheat, the farmer continues growing wheat because it is profitable even if yields are quite low. Another farmer practicing organic farming since 11 years (Farmer 12) claimed that the purpose of his crop rotation was to solve the problem of thistle and couch grass. The farmer remarked:

"Thistles are difficult to control and that is why I have three-four years of ley in the rotation. I also avoid growing wheat after wheat or barley. The disadvantage of my rotation is that couch grass propagates. The couch grass multiplies in the ley, especially if you have ley for three years, but they are not as stubborn as thistle".

Similar to several arable farmers, he reported thistles to be an important factor when deciding his crop rotation, which had not been mentioned by many farmers with livestock. However, Farmer 12 had four years between the ley crops, which is more than any other livestock farmer. According to his experience, two years of ley was not enough to control thistles. The risk of having three year leys in the rotation was also highlighted by this farmer. After three years of ley the problem with couch grass accelerated according to Farmer 12. This is evidence of a trade-off between controlling thistle and couch grass and this farmer prioritised the control of thistle, because he found couch grass easier to control by other means, supposedly through tillage. It is well known that perennial weeds can easily become a major problem if crop sequences are not properly planned and managed (Liebman & Dyck 1993) and that the occurrence of thistle decrease with the age of the ley crops, while this is not the case with couch grass (Håkansson 2003).Couch grass has a similar growth habit as the sown grasses and can therefore tolerate the frequent cuttings associated with harvest well (Cussans 1973), while creeping thistle is sensitive to cutting (Graglia et al. 2006).

A long-term organic farmer who had been raising beef cattle and sheep organically for 23 years (Farmer 10) did not follow a crop rotation. When asked what determined his rotation, the farmer replied:

"*I grow whatever suits me. I have a lot of ideas about different crops and rotation. But I can never decide in advance what I am going to grow in the coming year as my chosen crops sometimes die or fetch a lower price. As time goes on, it will tell. You have to change your plans in order to benefit according to each particular year and I buy feed sometimes in order to grow more cereals".*

This farmer did not seem to be interested in following a planned crop rotation because of several uncertainties. According to him, he could gain more by adapting to the prevailing conditions and market prices than following a planned rotation and this determined his crop rotation. Smit and Pilifosova (2003) reported that farmers who have experienced the effects of extreme events, e.g. extreme weather, can plan better to adapt to the impacts of future extreme events. Despite being a livestock farmer, his crop rotation strategy was similar to several of the arable farmers.

A long-term organic farmer (Farmer 11) who had been raising beef cattle organically for 23 years mentioned that the soil type in his farm was the most important determinant for his crop rotation. The farmer said:

"*If you run your farm organically, you should terminate the ley after a shorter length of time to take advantage of the nitrogen. If you don't, the nitrogen just leaches. But knowing is one thing and doing is another. The peat soils in my fields are mainly suitable for growing ley, it is difficult to grow cereals on them, and you easily get a lot of weeds. That is why we have mostly cereals on the mineral soils and ley on the peat soils".*

He grew mainly barley on the mineral soils and ley on the peat soils (soils with a relatively high percentage of organic matter). In spite of his awareness of the benefits of ley crops and crop rotation, he chose to grow his leys on the peat soils, because of the difficulties of producing good cereal crops without herbicides on these soils. A sheep farmer who converted to organic farming four years earlier (Farmer 14) claimed to follow a planned crop rotation in order to produce sufficient fodder on peat soils, with one year oats followed by three years of ley in the rotation. He shared similar experience as Farmer 11 on the difficulty of growing cereals on peat soils. The farmer commented:

"*Well, on the peat soils it is only oats, because wheat, barley and peas don't grow well on the peat soil and I don't know what other crops to grow. Oats is followed by ley for some years. It is mainly to establish a new ley crop that I have oats every fourth year and I do not need to buy feed from neighbours.*"

In summary, several long-term organic farmers were aware of the 'potential benefits' of practicing crop rotation, but they were generally quite flexible in their rotations and adapted them to soil type, climate, market, and weeds. The important considerations for the farmers were the number of years to keep the leys in the rotation to optimise weed control, residual effect of the leys, the possibility to grow cash crops and presumably the need for feed. The recently converted organic farmers seemed more eager to follow planned crop rotations and the main purpose of the crop rotation planning was to control weed propagation, especially thistle and couch grass. Most of the farmers in this group followed crop rotation rules quite diligently.

Pig and mixed livestock farmers

The main reason for following a planned crop rotation for a pig farmer who converted to organic farming three years earlier (Farmer 16) was to achieve good break crop effects. He practiced the following crop rotation:

Oats (under-sown with grass-clover) - Ley 1 - Ley 2 - Wheat/Barley - Oats- Pea

The farmer remarked on his crop rotation:

"*My rotation is to produce enough feed for my pigs. I avoid barley after barley in the rotation as there could be fungi (in the crops). Maybe my application of manures worsens the fungus situation. I am also trying to get rid of the weeds. I am a pig farmer but I grow ley to remove the weeds. I think it has reduced the problem with fungal diseases and also fertilised the soil*".

The farmer changed his earlier crop rotation because of his experience with fungal diseases and weeds in the crops. He related the occurrence of fungal diseases in his crops to growing barley for several consecutive years and also to the application of manures. He chose to follow a proper rotation with two years of ley even though the pigs did not consume much forage, as it offered other benefits such as reducing the problem of weeds and diseases and also improving the soil fertility. The increase in fungal disease with animal manure that the farmer report could probably be an effect of the resulting high nitrogen availability that is known to increase risk of fungal diseases, but, in general, animal manure is considered to promote crop health by increasing soil biological activity (van Bruggen 1995).

The crop rotation strategy of a farmer who had practiced organic farming for 25 years (Farmer 15) was based not only on economic and agronomic reasons but also on very strong ecological arguments. He practiced a highly diversified system with several farm income sources: pig, beef, dairy, sheep, poultry and cereals on 170 ha farmland.

He claimed to follow a planned crop rotation most of the time, but sometimes interchanged crops with similar properties, or changed crops as response to weather conditions. He gave the following statement on his crop rotation:

"*The aim of my crop rotation is to produce enough to make a profit, control pests and weeds and also enhance biodiversity. One goal is to have enough grains to sell, (which means) more than we consume, including household consumption. We also look into the resilience of the farm using different combination and ways of integrating crops and animals. The extension agent advised me to invest in one species to make greater profit. But I don't want to put all eggs in one basket."*

Although the extension agents have advised him to specialise in one type of farm enterprise in order to increase profitability, the farmer had deliberately diversified the farm with several crops and animal species. The farmer also mentioned that he thinks his farm will be more sustainable if he has income from diversified sources. He seems to prioritise long-term farm sustainability more than the short-term economic benefit. It has been shown earlier that some organic farmers have a long-term concern for sustainability and these farmers are willing to risk a reduced yield in the short-term for a good chance of a higher yield in the future (Mccan et al. 1997). Darnhofer et al. (2005) also suggested that farmers with this focus on sustainability are likely to be long-term organic farmers and that they are likely to be willing to risk foregoing incomes for the cause of organic principles. The farming ideals of Farmer 15 seemed to be deeply rooted in the principles of organic farming and his crop rotation with diverse crops and proper length of crop sequence fits well to the rules of crop rotation.

[Table 2 near here]

Concluding discussion

The study illustrates that farmers' past experiences with crop rotation and management greatly influenced the farmers' current crop rotation strategies. The case of arable farmers using 'Biofer' as a substitute for legumes is a good example where the convenience of use and short-term better economic return from consecutive cereal crops makes them choose cereal crops over legumes and perennial crops in the rotation. This allowed them to grow crops according to market demand and price without considering the best possible use of crop rotation. Although, this practice appears to be more of a conventional farming approach, it seems to be getting more common among organic farmers in many parts of the world (Lockie & Halpin 2005; Darnhofer et al. 2010; Oelofse et al. 2011). The intensification may also increase the extent to which organic farming relies on nutrient imports from conventional production as discussed by Nowak et al. (2013). The organic standards are characterised by a description of what is not allowed in organic farming rather than describing the positive practices. One of the difficulties of translating the principles of organic farming into practice is associated with the interpretation of those principles as there is no single or exact interpretation of these. Padel et al. (2009), Darnhofer et al. (2010) and Dinis et al. (2015) all point out specifically that the principles of organic farming are only partly expressed in the certification rules in relation to biodiversity, nutrient cycling etc. Many authors suggest that this can result in a type of organic farming which is very close to conventional farming but without the prohibited substances (Allen & Kovach 2000; Constance et al. 2008). The organic farmers in this study who are moving away from diverse crop rotation towards the use of purchased organic fertilisers and high-tech solutions of mechanical weeding could be seen as falling into this category. On the contrary, there were also farmers who had experienced the problem of diseases, weeds and low yield from their earlier rotation strategy that focused on producing as many cash crops (cereals) as possible, and who have changed their crop rotation strategies to address the problems.

The results shows that farmers decisions on their crop rotations are not necessarily based on the rules of crop rotations (Castellazzi et al. 2008), and the principles of organic agriculture (by IFOAM), but also by factors such as soil type, weeds, price, tradition, etc., as mentioned in the European Commission (2010) report. In addition, our study has identified important trade-offs which farmers have to consider when deciding their crop rotations. The case of arable farmers preferring to grow more cereal crops than perennial ley or annual legumes fits with the ideas of Watson et al. (2002), as these crops are of little economic benefit and also do not increase the total supply of nutrients other than nitrogen. It is logical for the arable farmers to focus on growing profitable cereal crops more frequently in the rotation as their income comes from crops only. However, the evidence of several livestock farmers preferring to grow cereal crops and purchase feed is a general cause for concern about the reliance of organic farming on external (conventional) sources. Kirchmann et al. (2008) reported that 75% of organic mixed farms in Austria and Sweden imported fodders from external sources, mainly from conventional farming. Neighbouring farmers with and without animals could also collaborate in order to use resources more efficiently at a regional scale, allowing some specialisation while keeping some of the advantages of the diversified systems.

Most of the livestock farmers in the study region, excluding the dairy farmers, have 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 evident amongst the long-term organic livestock farmers (more than 10 years of certified organic farming) within the group. Their farming aims were to produce sufficient feed as well as different cash crops. The recently converted organic livestock farmers tended to be specialised and focused on producing feed for their livestock and grew few crop species. Zander (2005) showed that personality of the farmer is the key driving factor for diversification among organic farmers in Germany and that presence of highly qualified labour on the farm was a pre-condition to successful diversification. Perhaps, the long-term organic farmers in our study had gained experience and skills through many years of organic farming and this might be the reason why they had more diversified systems than the recent organic farmers. The case of long-term organic farmers practicing more diversified farming and adhering to the principles of organic farming than the recently converted ones was also reported in other parts of Europe (Best 2008, Padel 2008; Dinis et al. 2015).

We could distinguish three different crop rotation strategies; strict, flexible and liberal crop rotation. Farmers practicing strict crop rotation strategies have 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 practicing 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 farmers practiced strict crop rotation and their strategy appeared to be mainly related to controlling weeds and diseases in the cereals. Flexible and liberal crop rotation strategies were more associated with long-term organic farmers and their rationale was to adapt to, or gain from the changing conditions such as market and weather.

In conclusion, farmer's past experiences with the trade-offs between different practices greatly influenced their crop rotation strategies, i.e. strict, flexible or liberal. Irrespective of the farm type, the most important trade-off was to grow frequent cereal cash crops at the expense of ley and legumes in the rotation leading to flexibility in their crop rotations. The rotation strategies of long-term organic farmers were much influenced by organic principles and they generally incorporated ley crops in their rotations. Their rationale for flexible and liberal crop rotations was to be able to adapt to changing conditions. Recently converted organic farmers often practiced strict rotation and followed the rules of crop rotations to control weeds and diseases. Farmers who chose crops without an intended crop-rotation (liberal) claimed to continuously adapt to prevailing economic and agro-environmental conditions as well as their personal preferences, and their rotation strategy tend to deviate from the rules of crop rotation and organic agriculture. Most livestock farmers built their crop rotation around ley and forage and their overriding aim was to produce sufficient feed, but some preferred to grow more cereals for sale and purchase some feed for better economic return. We conclude that despite the multifunctional benefits of ley and crop rotation in organic system, many farmers tend to overlook it for short term economic benefits. As a result, these farmers may need to invest in technology or labour for weed control and become more reliant on other external inputs.

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References

Allen P, Kovach M. 2000. The capitalist composition of organic: the potential of markets in fulfilling the promise of organic agriculture. Agr Hum Val. 17: 221–232.

Angus JF, Kirkegaard JA, Hunt JR, Ryan MH, Ohlander L, Peoples MB. 2015. Break crops and rotations for wheat. Crop Pasture Sci. 66:523–552.

Aubry C, Papy F, Capillon A.1998. Modelling decision-making processes for annual crop management. Agric Syst. 56:45–65.

Bachinger J, Zander P. 2007. ROTOR, a tool for generating and evaluating crop rotations for organic farming systems. Eur J Agron. 26:130–143.

Bertsen, J, Grant R, Olesen JE, Kristensen IS, Vinter FP, Møllgaard JP, Petersen BM. 2006. Nitrogen cycling in organic farming systems with rotational grass-clover and arable crops. Soil Use Manage. 22:197–208.

Best H. 2008. Organic agriculture and the conventionalization hypothesis: a case study from West Germany. Agr Hum Val. 25:95-106.

Buerstmayer H, Krenn N, Stepha, U, Grausgruber H, Zechner E. 2007. Agronomic performance and quality of oat (Avena sativa L.) genotypes of worldwide origin produced under central European growing conditions. Field Crop Res. 101:345–351.

Bullock DG. 1992. Crop rotation. Crit Rev Plant Sci. 11:309-326.

Castellazzi MS, Wood GA, Burgess PJ, Morris J, Conrad KF, Perry JN. 2008. A systematic representation of crop rotations. Agric Syst. 97(1):26-33.

Constance D, Choi JY, Lyke Ho-Land H, 2008. Conventionalization, bifurcation, and quality of life: certified and non-certified organic farmers in Texas. South Rural Sociol. 23(1):208–234.

Cussans GW. (1973) A study of the growth of *Agropyron repens* (L) Beauv. in a ryegrass ley. Weed Res. 13:283-291.

Darnhofer I, Schneeberger W, Freyer B. 2005. Converting or not converting to organic farming in Austria: Farmer types and their rationale. Agric Hum Val. 22(1):39-52.

Darnhofer I, Lindenthal T, Bartel-Kratochvil R, Zollitsch W. 2010. Conventionalisation of organic farming practices: from structural criteria towards an assessment based on organic principles. A review. Agron Sustain Dev. 30(1):67-81.

De Wit J, Verhoog H. 2007. Organic values and the conventionalization of organic agriculture. NJAS-Wag J Life Sc. 449–462.

Dinis I, Ortolani L, Bocci R, Brites C. 2015. Organic agriculture values and practices in Portugal and Italy. Agric Syst. 136:39-45.

Dury J, Garcia F, Reynaud A, Bergez JE. 2013. Cropping-plan decision-making on irrigated crop farms: A spatio-temporal analysis. Eur J Agron. 50:1-10.

European Commission. 2010. Environmental effects of different crop rotations in the European Union. Final report.[cited 2014 Nov 10]. Available from: http://ec.europa.eu/environment/agriculture/pdf/BIO_crop_rotations%20final%20report_rev%20executive%20summary_.pdf

EU. 2007**.** Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91**.** [cited 2015 Dec 07]. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32007R0834

Flaten O, Lien G, Koesling M, Valle PS, Ebbesvik M. 2005. Comparing risk perceptions and risk management in organic and conventional dairy farming: Empirical results from Norway. Livest Prod Sci. 95(1):11–25.

Gerhardt RA. 1997. A comparative analysis of the effects of organic and conventional farming systems on soil structure. Biol Agric Hortic. 14:139-157.

Graglia E, Melander B, Jensen RK. 2006. Mechanical and cultural strategies to control Cirsium arvense in organic arable cropping systems. Weed Res. 46:304-312.

Håkansson S. 2003. Weeds and weed management on arable land: an ecological approach. CABI Publishing.Wallingford, UK.

IFOAM. 2005. The principles of organic agriculture. [cited 2015 Sep15]. Available from: http://infohub.ifoam.bio/en/what-organic/principles-organic-agriculture

Johnston AE, McEwen J, Lane PW, Hewitt MV, Poulton PR, Yeoman DP. 1994. Effects of one to six year old ryegrass–clover leys on soil nitrogen and on subsequent yields and fertilizer nitrogen requirements of the arable sequence winter wheat, potatoes, winter wheat, winter beans (Vicia faba) grown on a sandy loam soil. J Agric Sci. 122:73–89.

Jonason D, Andersson GK, Ockinger E, Rundlöf M, Smith HG, Bengtsson J. 2011. Assessing the effect of time since transition to organic farming on plant and butterflies. J Appl Ecol. 48:543-550.

Jonason D, Andersson GK, Ockinger E, Smith HG, Bengtsson J. 2012. Field scale organic farming does not counteract landscape effects on butterfly trait composition. Agr Ecosyst Env. 158:66-71.

Karlen DL, Varvel GE, Bullock DG, Cruse RM. 1994. Crop rotations for the 21st century. Adv Agron. 53:1-45.

Kirchmann H, Kätterer T, Bergström L. 2008. Nutrient supply in organic agriculture–plant availability, sources and recycling. Organic Crop Production–Ambitions and Limitations. Springer, Netherlands. 89-116.

Kvale S. 1996. Inter Views: An introduction to qualitative research interviewing. Sage Publications. Thousand Oaks, CA.

Liebman M, Dyck E. 1993. Crop rotations and intercropping strategies for weed management. Ecol Appl 3(1):92-122.

Lockie S, Halpin D. 2005.The ‘conventionalisation’ thesis reconsidered: Structural and ideological transformation of Australian organic agriculture. Sociologia ruralis. 45(4):284-307.

Longhurst R. 2003. Semi-structured interviews and focus groups. In: Clifford N, French S, Valentine G, editors. Key methods in geography. Sage Publications Ltd. London; p.103-114.

Mccann_E, Sullivan S, Erickson D, De Young R. 1997. Environmental Awareness, Economic Orientation, and Farming Practices: A Comparison of Organic and Conventional Farmers. Env Manage. 5:747-758.

Moncada KM, Sheaffer CC. 2010. Weed management. In Moncada K, Sheaffer CC, editors. Risk Management Guide for Organic Producers. Saint Paul, MN: University of Minnesota.

Nowak B, Nesme T, David C, Pellerin S. 2013. To what extent does organic farming rely on nutrient inflows from conventional farming? *Environ Res Lett.* 8 044045.

Oelofse M, Høgh-Jensen H, Abreu LS, Almeida GF, El-Araby A, Hui OY, Sultan T, de Neergaard A. 2011. Organic farm conventionalisation and farmer practices in China, Brazil and Egypt. Agron Sustain Dev. 31(4):689-698.

Oelofse M, Jensen LS, Magid J. 2013. The implications of phasing out conventional nutrient supply in organic agriculture: Denmark as a case. Organic Agriculture 3(1):41-55.

Padel S. 2008. Values of organic producers converting at different times: results of a focus group study in five European countries. Int J Agr Resour Gov Ecol. (7):63-77.

Padel S, Röcklinsberg H, Schmid O. 2009. The implementation of organic principles and values in the European Regulation for organic food. Food Policy. 34 (3):245–251.

Papadopoulos A, Mooney SJ, Bird, NRA. 2006. Quantification of the effects of contrasting crops in the development of soil structure: an organic conversion. Soil Use Manage. 22:172–179.

Persson T, Bergkvist G, Kätterer T. 2008. Long-term effects of crop rotations with and without perennial leys on soil carbon stocks and grain yields of winter wheat. Nutrient Cycling in Agro-ecosystems. 81:193–202.

Power B, Rodriguez D, DeVoil, P, Harris G, Payero J. 2011. A multi-field bio-economic model of irrigated grain–cotton farming systems. Field Crops Res. 124:171–179.

Smit B, Pilifosova O. 2003. Adaptation to climate change in the context of sustainable development and equity. Sustain Dev. 8(9):9.

Swedish Board of Agriculture. 2011. Year book of Agricultural Statistics .2011. SCB-Tryck, Örebro, Sweden

Van Bruggen AH. 1995. Plant disease severity in high-input compared to reduced-input and organic farming systems. Plant disease. 79(10):976-84.

Watson CA, D, Atkinson D, Gosling P, Jackson LR, Rayns FW. 2002. Managing soil fertility in organic farming systems. Soil Use Manage. 18:239-247.

Zander K. 2005. Diversification and specialisation as development strategies in organic farms. 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008. [cited 2014 Nov 02]. Available from: http://orgprints.org/view/projects/conference.html

Öhlmér B, Olson K, Brehmer B. 1998. Understanding farmers' decision making processes and improving managerial assistance. Agr Econ. 18:273-290.

List of Tables

Table 1. List of keywords for the interviews

A .Farm Overview:

1. Size; Labourers; Number of crops, animals. Why?
2. History- ownership, farming type (crops/animals)

B .Farming/cropping systems:

1. Organic/conventional: since when, why?
2. Crop sequence and rotation in the farm
3. Purpose of the sequence/rotation
4. Pros and cons of the rotations , e.g. effect on soil, water, disease/weeds, yield, price
5. Change in crop rotations in the recent past.
6. Source/knowledge of crop rotation from where/whom?
7. Any Intercropping, how and why?
8. Annual crop distribution
9. Crops in the farm (according to area, economic expenditure and benefits),
10. Crops/crop rotations that are most challenging to grow, and why, how it is overcome?
11. Cash crops/how much for internal use? Where he sells, why? Any contract?

C. Decisions:

1. Sowing and harvesting time
2. When and how the decisions on crop choices are taken?

D. Management:

1. Fertiliser/manures and amount (for different crops), internal or external
2. Farm expenditure (ranking)
3. Farm challenges (rank)
4. Subsidies and market price on type of crop/farming

E. Farmers' information:

1. Age: Farming education; Any techniques he learnt from education or visiting farms abroad

Table 2. Summary of general farm characteristics and farmer's crop rotations, typical sequence or crops grown, and type of rotation strategy, i.e. strict (always the same crops grown in rotation if at all possible), flexible (aim for a special rotation and adjust according to circumstances) and liberal (no special rotation). Ley refers to a crop mixture of red 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	Grow 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) -	Strict

					ley - ley - winter wheat	
7	Dairy	105	90	13	Barley and pea (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	Grow at least two years of ley and also other crops such as winter wheat, barley and oats	Liberal
11	Beef	34	35	23	Grow 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 - oat- pea- 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 root weeds between incorporation of ley crop and sowing of winter wheat.