Integrating horticultural and arable crops

– a sustainable way to increase vegetable production in Scania?

Integrering av trädgårds- och jordbruksgrödor – ett hållbart sätt att öka produktionen av grönsaker i Skåne?

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Abstract

Modern arable production is associated with a highly homogenous landscape with few cultivated species and is relying heavily on external chemical inputs. Intensive vegetable production, on the other hand, is associated with environmental costs such as increased risk of nutrient leaching and loss of soil organic matter. A high crop diversity is instrumental in minimizing the negative environmental impact of agriculture and increasing the ability of agroecosystems to deliver ecosystem services. Increasing the complexity of the crop sequence by integration of horticultural and arable crops is a way to increase temporal and spatial diversity.

The national food strategy of Sweden calls for increased production and for meeting consumer demand for locally produced food. This suggests that an increase in production of vegetables and other horticultural crops is desirable. Integration of horticultural and arable crops has the potential to mitigate some of the negative effects of a pure vegetable rotation. Integrated rotations also afford benefits of a greater diversity that are lacking in short arable rotations or monocultures.

In this study, the aim has been to explore the opportunities associated with integrating arable and horticultural crops as a way to increase the amount of vegetables grown in Scanian fields. This was done by exploring the current prevalence of integrated crop rotations, based on data provided by the Swedish Board of Agriculture, and the perceptions and attitudes of farmers through a web-based questionnaire and a series of semi structured interviews.

If potatoes are categorized as a horticultural crop, 10.0 percent of the Scanian farm enterprises produce both arable and horticultural crops according to the results of this study. If potatoes are categorized as an arable crop, the percentage is 6.9 instead. Very few farmers grow exclusively horticultural crops. Integration is more common in the plains and middle farming area than in the northern parts of the region, and among farms with an area larger than 100 hectares.

The results suggest that farmers believe that integrating horticultural and arable crops has a positive effect on profitability and that this comes at the price of a heavier workload when compared to crop rotations with only arable crops. The participants offer few opinions regarding the environmental impact of integrated rotations. Soil health is believed by the participants to be negatively affected by vegetable crops, due to more open soil, irrigation, and tillage, while grains and ley improve soil health by increasing soil organic matter and improving structure.

Physical characteristics of the farm and economic factors rank highest among factors influencing decision making, in general terms. Workload and time constraints are also factors, and interest, personal well-being, and force of habit feature among the responses. Several participants express a wish to care for the environment but do not allow environmental concerns to motivate their crop choices. In terms of what is needed to take the step to change one's crop rotation, better market opportunities and more knowledge are required. Obstacles to change are tangible constraints such as soil type and high investment requirements, and a vaguer notion of a high threshold to overcome. Networks and partnerships can make change easier.

To promote integrated crop rotations, access to the personal and external components that are needed for that opportunity to be a viable option for farmers should be facilitated. This includes facilitating marketing and sales, improving access to capital, improving risk management mechanisms, funding research, and promoting advisory service, networking and collaborations.

Keywords: Horticulture, agriculture, vegetables, crop rotation, crop sequence, diversification, integration, ecosystem services, farmers' attitudes

Preface and acknowledgements

This project started with curiosity. Can we grow more vegetables here in Scania? How about doing it by increasing the diversity of crop sequences?

I wanted to understand the opportunities and obstacles associated with crop rotations including both arable and horticultural crops – in this thesis termed integrated crop rotations – and I especially wanted to learn from those closest to the practical reality of the thing: the farmers.

It has been a bumpy ride at times. Timing was not ideal, as the pandemic has meant many hours of lonely work, without the chance of spontaneous meetings and interactions that comes with being on campus.

But this bumpy ride has proved a great occasion for learning: about diversification of cropping systems, the consequences of farming in relation to ecosystem services, farmers' decision making, and arable crops – a field into which I, coming from the horticultural angle, had limited insight. I have learnt about the methodological intricacies of research questionnaires and semi structured interviews, and how to wrestle an Excel file with a staggering 28 881 rows (I actually believed my laptop would catch fire at one point).

Most of all, I have had the privilege of getting a glimpse of the real world through the eyes of the eight farmers that participated in my interview study. I am immensely grateful to them for giving so generously of their time, for their patience with my inexperience, and for the insights they provided. My sincerest thanks are owed to them.

I must also mention and thank the farmers who took the time to respond to my survey – I only wish there had been more of you.

I would like to thank my supervisor Linda-Maria Dimitrova Mårtensson, for putting me on the trail, for clear-sighted advice, and for well-timed words of encouragement and wisdom. Thanks also to Jan-Eric Englund for advice on statistical analysis.

Finally, to my family: for always being there, never giving me a hard time when the completion of the thesis kept being pushed back, and for providing comfort when my confidence reached new low points, I give you all my love and gratitude.

Table of contents

List of tables

List of figures

1. Introduction

1.1. Background

Modern capital- and technology-intensive agriculture has a low degree of diversity and is highly dependent on chemical inputs (IPES-Food, 2016; Gliessman, 2014). It lacks the self-regulating mechanisms of traditional agricultural systems where resources were circulated within the farm and the farming practices were conducive to upholding ecosystem services such as biological control mechanisms and nutrient cycling. Intensification has led to a more homogenous landscape, with deleterious effects on biodiversity (Winqvist et al., 2012). Short (two- or three-year) rotations and monocultures are often associated with yield losses over time, a fact that is hypothesized to depend on a combination of factors e.g. plant pathogen build-up, autotoxicity of the crop, and nutrient availability (Bennett et al., 2012). Monoculture plantations have the most detrimental effect on local scale biodiversity of all cropping systems (Anand et al., 2010).

Vegetable production requires more intensive management than arable cropping systems, with higher fertilization rates, tillage frequency and input of water and nutrients (Lu et al., 2021). The price for high productivity is often a loss of supporting and regulating ecosystem services (Wauters et al., 2021), where the higher water requirements and therefore higher irrigation intensity associated with vegetable production also increases the risk of runoff and leaching (Li et al., 2019b). N_2O (nitrous oxide) emissions are also generally higher in vegetable production compared to other cropping systems, due to higher nitrogen (N) application rates (Wang et al., 2018).

Switching from cereal production to intensive vegetable production has been shown to reduce soil organic carbon content and soil aggregate stability, due to intensive tillage and reduced input of crop residues (Lu et al., 2021; Guo et al., 2020; Ogle et al., 2005). When soils are disturbed through tillage, the soil organic matter is exposed and subjected to more rapid mineralization by the microbial community than in no-till systems or permanent pastures (Sarker et al., 2018). This in turn leads to mineralization and release of nutrients (e.g. N and P), making them available for plant uptake and/or leaching, while a system with less disturbance

would retain larger stores of the nutrients (albeit largely in immobilized form). The structure of the soil is a major determinant of water infiltration, retention and availability, root development, gas exchange, and conditions for soil biota (Pires et al., 2017). Tillage contributes to a homogenization of the soil, with fewer large pores and thus lower water infiltration capacity.

High rates of fertilizer application can lead to an accumulation of surplus phosphorous (P) in the soil, increasing the risk of leaching and pollution of surface water bodies (Lu et al., 2021; Yan et al., 2013). Excessive available P inhibits plant mechanisms designed to increase P uptake, including symbiosis with arbuscular mycorrhizal fungi (AMF) and exudation of certain enzymes and organic acids. As root exudates play an important role in soil particle aggregation, a surplus of P will also have a detrimental effect on soil structure.

Intensive tillage and fertilization have a negative impact on soil fungal biomass and disrupt networks of AMF (Mariotte et al., 2018; de Vries & Bardgett, 2012). Such networks play an important role in nutrient cycling. Reducing N inputs, reducing tillage intensity and including legumes and grassland plant communities in the crop sequence are management options that will promote fungal-dominated soil food webs.

1.1.1. The role of crop diversity

To minimize the negative environmental impact of agriculture and to ensure sufficient productive capacity for the needs of a growing global population, various diversification strategies are increasingly employed – rethinking the value of highly intensified cropping systems with very few cultivated species (Beillouin et al., 2019). A diversified farming system is defined by Kremen et al. (2012) as a system where functional biodiversity is intentionally included on numerous spatial and/or temporal scales in order to generate essential ecosystem services to agriculture. This is achieved by applying multiple practices, developed via both traditional and scientific knowledge. Figure 1 illustrates how different practices fit into the system on different scales. Diversification is hypothesized to provide critical inputs, thereby reducing ecological externalities and the need for off-farm inputs (Kremen & Miles, 2012).

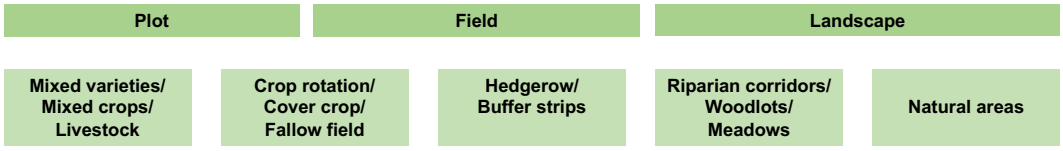

Figure 1. Different strategies for diversification, on a plot, field, and landscape scale. Adapted from Kremen et al. (2012).

Crop diversification is one strategy to incorporate agrobiodiversity into the cropping system. Increasing the length of the crop rotation (i.e. including a larger

number of species) results in an increase in temporal diversity and spatial diversity if crops are grown simultaneously on different patches.

A greater species richness means a greater richness in species traits, on average, thus increasing the chance of 'niche complementarity' between groups of species (Loreau & Hector, 2001; Mulder et al., 2001; Tilman et al., 2001; Tilman et al., 1997). Such complementarity ensures a more efficient use of resources, leading to a higher average productivity and providing a buffering effect on temporal variations in community function (Yachi & Loreau, 1999; Tilman et al., 1997).

Crop rotation is presumed to interrupt and prevent the build-up of pests and pathogens (Henry et al., 2019; Rosa-Schleich et al., 2019; Bommarco et al., 2013; Kremen & Miles, 2012). Species-rich systems also have a greater abundance of natural enemies of herbivore pests and reduced amount of crop damage compared to species-poor systems (Letourneau et al., 2011). By including flowering crops in the rotation, both diversity and richness of pollinators may increase (Bommarco et al., 2013).

Diversified crop rotations are associated with improved weed control, even when combined with a drastic reduction of herbicide use (Rosa-Schleich et al., 2019; Bommarco et al., 2013; Davis et al., 2012). A diverse community of weeds is less competitive in relation to the crop than a single dominating weed species (MacLaren et al., 2020). A diversified crop rotation leads to a higher diversity among weeds, since it entails diversifying management practices, e.g. type and timing of tillage and seedbed preparation methods (Weisberger et al., 2019; Sosnoskie et al., 2006; Barberi, 2002).

The soil provides essential supporting ecosystem services for agricultural production (Bommarco et al., 2013; Kremen & Miles, 2012; Smukler et al., 2012; Altieri, 1999). This includes processes involving decomposition, nutrient cycling, pest and disease regulation, soil structure, infiltration capacity, water retention capacity, and resistance to erosion. The main management practices sustaining or enhancing these services are currently understood to be increasing soil organic matter and crop rotation.

Richness and diversity of the soil microbial community are positively impacted by rotations compared to monocultures (Li et al., 2019a; Venter et al., 2016). The composition of the soil microbiome is influenced by the crops included in the rotation (Mariotte et al., 2018; Venter et al., 2016), due to differences in both plant rhizodeposit characteristics, influencing the rhizosphere microbial community (Berg & Smalla, 2009), and litter abundance and quality, influencing microbial decomposer diversity (Kennedy, 1999).

Increasing the complexity of the crop rotation results in an increase in soil organic carbon content, particularly in soils under conventional tillage management (West & Post, 2002). Extending the crop rotation to include a cereal crop is a possible way to reduce or reverse soil degradation associated with intensive

vegetable production, due to the positive effect of incorporating cereal crop residue in the soil (Lu et al., 2021). The use of winter cover crops increases the organic carbon content of the soil (Comin et al., 2018; Ogle et al., 2005).

Diverse crop rotations increase nitrogen recovery in crop and soil (Gardner & Drinkwater, 2009), and inclusion of leguminous plants contributes biological nitrogen fixation in symbiosis with rhizobia (Mylona et al., 1995). Reducing external input of fertilizer without compromising yield can therefore be achieved by inclusion of legumes in the crop rotation (Sánchez-Navarro et al., 2019; St Luce et al., 2015). In a crop sequence including both arable and vegetable crops, incorporation of crop residues (and/or green manure or cover crop residues) can also serve as a significant source of nitrogen for subsequent crops (Råberg et al., 2019; 2018; Guttormsen 2000). Biochar amendment has been suggested to allow lower applications of chemical fertilizer with maintained yield of vegetables grown in a horticultural/arable rotation (Qi et al., 2020). Crop rotation can also play a role in making more effective use of existing sources of phosphorous in the soil, by taking advantage of readily mineralizable organic forms accumulated by e.g. ley phases or green manure crops (Conyers & Moody, 2009).

Diversification of cropping systems, particularly temporal diversity created by adopting more complex crop rotations, is suggested as a means to increase resilience and maintain production levels in a warmer climate with more frequent climate extremes (Bullock et al., 2017; Gaudin et al., 2015; Lenssen et al., 2014; Mijatović et al., 2013; Davis et al., 2012; Lin, 2011). Different taxa responding in different ways to environmental stress in a complementary fashion affords the system greater resilience when subjected to disturbances (Bullock et al., 2017).

80 percent of the global terrestrial carbon pool is stored in the soil and 20 percent of the soil carbon is stored in agricultural soils (Wood et al., 2000, in Bommarco et al., 2013). Compared with conventional farming systems, diversified systems and longer crop sequences are associated with higher levels of carbon sequestration (Kremen & Miles, 2012; Drinkwater et al., 1998). However, changes in soil carbon are influenced by the types of plants included in the rotation.

Regarding the economic effects of diversified crop rotations on farm level, there is evidence that there are benefits for the individual farmer mainly in a long-term perspective (Rosa-Schleich et al., 2019). Diversification potentially reduces the need for external inputs and thereby costs.

Yield resilience through crop diversity is a means to reduce risk, especially exposure to downside risk or crop failure (Chavas, 2008; Di Falco & Chavas, 2006; Helmers et al., 2001). There also appear to be economies of scope, i.e. the aggregate production of several outputs is more efficient than specialized production, largely due to complementarities between different outputs such as crops in a crop rotation benefitting from each other (Chavas, 2008). There is a negative relationship

between size of farm and economies of scope, implying an incentive for diversification especially for smaller farms.

Introducing high-value crops such as fruit or vegetables into the rotation can provide opportunity for increased farm revenue (FAO, 2020). Globally, the demand for fresh produce is rising, especially in high-income countries.

1.1.2. The National Food Strategy of Sweden

The National Food Strategy, adopted by the Swedish parliament in 2017, aims at increased, sustainable food production (Gov. Bill 2016/17:104). The overarching goal is a competitive food sector, contributing to an increase in total production, fulfilment of national environmental objectives and sustainable development throughout the country. A high degree of self-sufficiency with regards to food is recognized as part of the country's ability to uphold supply of necessities in times of crisis, especially where international trade is curtailed for longer periods of time. An increase in production is seen as a means to increase the degree of self-sufficiency. The National Food Strategy also states that the increase in production should meet consumer demand, for example for locally produced and/or organic fruit and vegetables.

The current trend in consumer demand shows increased focus on locally produced vegetables (Selling, 2020; Fernqvist & Göransson, 2017). Representatives from both wholesalers and retailers report an increased demand for Swedish produce.

Sweden is a net importer of food and agricultural products (Strandberg & Lind, 2020). The balance of trade is especially negative for fruit and vegetables. At present (data from 2019) Sweden is self-sufficient only in cereals (Swedish Board of Agriculture, 2019a). Sweden is a net exporter of cereals with a market share of domestic production that has been above 100% since the country became a member of the EU in 1995. According to preliminary data for 2021/2022, 16% of the total cereal production of nearly 6 000 000 tons (disregarding import and reserves) is used as human food, 13% is used for industrial purposes, and around one-third each is exported and used as fodder (Swedish Board of Agriculture, 2022a). Swedish carrots consistently supply approximately 90% of the demand, while the share of Swedish onion has had a positive development, now accounting for around 70% of the market. 70% is also the market share for domestically produced potatoes and strawberries (Swedish Board of Agriculture, 2019a).

1.1.3. Sweden's environmental quality objectives

Sweden's environmental policy is expressed through a system of environmental quality objectives, adopted by the Swedish parliament in 1999 (Gov. Bill 2000/01:130; Sveriges miljömål, 2020). The overarching aim is expressed in the

Generation goal: To pass on to the next generation a society where the major environmental problems have been solved, without causing damage to health and environment in other countries. Five principles or values form the fundament: human health, biodiversity and the natural environment, the cultural environment and historical values, the long-term productive capacity of ecosystems, and wise management of natural resources (Gov. Bill 2000/01:130).

Several of the 16 environmental quality objectives, adopted in 1999 and 2005, (Sveriges miljömål, 2020) are closely linked to the agricultural and horticultural sectors, for instance 'a varied agricultural landscape', 'a rich diversity of plant and animal life', 'reduced climate impact', 'a non-toxic environment', 'zero eutrophication', 'flourishing lakes and watercourses', 'high-quality ground water' and 'thriving wetlands', as well as the generation goal. The relation between these objectives and agriculture/horticulture is recognized in the National Food Strategy (Gov. Bill 2016/17:104).

According to the objectives, the value of the agricultural landscape and soil for biological production and food production shall be protected and the land shall be farmed in a way that promotes biodiversity, minimizes environmental damage, and maintains important ecosystem services (Sveriges miljömål, 2020). Upholding the long-term productive capacity of the soil is emphasized, as well as maintaining a healthy soil with respect to structure, nutrient content, organic content, and sufficiently low pollution levels (Gov. Bill 2000/01:130). Cultural values as well as habitats and ecosystems shall be preserved and protected (Sveriges miljömål, 2020). It is noted that two parallel trends are posing threats to many species and habitats in the agricultural landscape and lead to an observable negative trend in biodiversity: the replacement of traditional agricultural management practices in favour of increasingly intensified and specialized farming systems in some parts of the country, and, reversely, the abandonment of farmland and closing of farms in other parts. Scania – the geographical focus of this study – is an example of the first trend (Dänhardt et al., 2013).

A rich diversity of plant and animal life is depicted as having a role in maintaining the resilience – the ability to deal with disturbances and adapt to changes, such as a changed climate – of ecosystems, enabling them to continuously deliver ecosystem services and contribute to climate change mitigation and adaptation (Sveriges miljömål, 2020).

1.1.4. Farm decision making

Farmers are often assumed to possess a high degree of risk aversion – in the sense that an increased variation in yield, even with maintained mean yield, is deemed unfavourable (Di Falco & Chavas, 2006; Chavas, 2004) – and may thus have an incentive to choose crops that reduce the variance of results. 'Downside risk aversion' is exhibited by farmers that are averse to exposure to unanticipated low

returns, suggesting that such farmers have an incentive to make decisions that reduce the skewness of yield, e.g. the likelihood of crop failure (Di Falco & Chavas, 2006; Menezes et al., 1980). In other words, avoiding low or negative income is, by many, deemed more important than earning a high income (Greiner et al., 2007). However, farmers vary greatly in their level of risk aversion, which influences their decisions (Pannell et al., 2006).

Farmers are (in most cases) entrepreneurs; thus, economic considerations matter in decision making, and the goals of wealth and economic security can be strong motivators – although economists tend to put greater emphasis on economic motivators than for example sociologists, according to Pannell et al. (2006). For instance, adoption of new practices is described as being conditioned upon there being a financial return, either directly, through reduced costs or increased earnings, or indirectly, e.g. through the appearance of new market niches (Dias et al., 2014). Farmers are expected to focus on the economic value added to their business and largely disregard the contribution of their decisions to negative or positive externalities (Dias et al., 2014; Jackson et al., 2007).

Macro-economic policies and institutions can therefore influence decision making by creating incentives, e.g. through tax breaks and subsidies (Pascual & Perrings, 2007). Historically and globally, such interventions have often resulted in creating a bias in favour of modern intensified agriculture, but they also potentially play a role in creating incentives for practices geared toward conservation or creation of ecosystem services (Pascual & Perrings, 2007; Tilman et al., 2002). Besides incentives, regulations and planning (e.g. mandatory conservation zones etc.) can steer farmers' decisions in the desired direction. Public investments in research and industry infrastructure have been suggested as instruments in increasing crop diversity, but effectiveness is contingent on the desired outcome being economically competitive for the individual farmer, and the desired change being compatible with the existing cropping system (Maaz et al., 2018).

The farm must be profitable, but several authors describe profitability as a means, not an end in itself (Farmar-Bowers & Lane, 2009; Pannell et al., 2006; Öhlmér et al., 1998). Business decisions are tools to fulfil aspirations or motivations. These have been found to include keeping the farm in the family and wanting to stay in business to be able to continue being a farmer, but also living up to one's values or ethics, being a responsible citizen, enjoyment, and being part of a social context. Intrinsic motivations such as attachment to the land, aesthetic appreciation, job satisfaction and the ethical value of producing high quality food are high-ranking motivators (Greiner et al., 2007).

Decisions to change or diversify farm activities can be resisted based on the challenge they pose to the identity and social status of being a 'good farmer', according to Burton (2004). Keeping a tidy farm and producing a high yield confers

pride and shows respect for the traditional custodial role of the farmer, rewards that can sometimes override the importance of earnings.

Moral dimensions sometimes play a role in decision making, for instance in organic farming (Verhoog et al., 2003). Concepts of 'naturalness' as a desirable trait, respect for all living beings, and the farmer as a steward of the land can be part of the process of evaluating different options.

1.2. Problem statement

Modern, intensive arable production is associated with a highly homogenous landscape with few cultivated species and is relying heavily on external chemical inputs. Intensive vegetable production, on the other hand, is associated with environmental costs such as increased risk of nutrient leaching and loss of soil organic matter. A high crop diversity is instrumental in minimizing the negative environmental impact of agriculture and increasing and/or preserving the ability of agroecosystems to deliver ecosystem services. Increasing the complexity of the crop sequence by integration of horticultural and arable crops is a way to increase temporal and spatial diversity in the agroecosystem.

The national food strategy of Sweden calls for increased production, greater self-sufficiency and for meeting consumer demand for locally produced food – especially fruit and vegetables. This suggests that an increase in production of vegetables and other horticultural crops is desirable. Previous research shows that integration of horticultural and arable crops has the potential to mitigate some of the negative effects of a pure vegetable rotation, which in turn suggests that integrated crop rotations constitute a suitable system within which to boost vegetable production. Integrated rotations also afford benefits of a greater diversity that are lacking in short arable rotations or monocultures.

Expanded use of integrated rotations can therefore play a role in working towards fulfilling the aims of both the food strategy and the national environmental quality objectives. As decisions on crop rotations are made on the farms, the perception and attitudes of farmers are a crucial component in understanding the potential of such a development.

1.3. Aim and objectives

1.3.1. Aim

The aim of this study is to explore the opportunities associated with integrating arable and horticultural crops as a possible way to increase the amount of horticultural crops, chiefly vegetables, grown in Scanian fields.

1.3.2. Objectives

The objectives are to investigate the current prevalence of integration of arable and horticultural crops among farmers in Scania, to explore how such integration is perceived by farmers, and what drivers and impediments to increased integration that they can identify.

1.3.3. Research questions

- How common is it that farmers in the study area include both arable and horticultural crops in their crop sequence and how does this differ between geographical areas within Scania, and farms of different size?
- How do farmers perceive integration of arable and horticultural crops with regard to its effects on economic, environmental, and other factors?
- What incentives and disincentives are identified by farmers in relation to crop sequences including both arable and horticultural crops, and how does this affect their motivation to adopt or not adopt such crop sequences?

1.3.4. Delimitations

The study is limited to systems involving a field crop sequence[1], restricting the horticultural crops under consideration to field grown vegetables and soft fruits and excluding for example greenhouse production and perennial cultures like orchards. The geographical area studied is limited to the province of Scania in southern Sweden. In analysing the current prevalence of integrated crop rotations, data from 2020 is used.

[1] 'Crop sequence' and 'crop rotation' are regarded by some authors as having different meanings: "In rotations different crops are grown in a fixed order year after year but in sequences the order is not necessarily repeated. The term 'sequence' captures the flexibility that is a feature of aware farm management" (FAO Crop & Grassland Service, 2003). The terms are used interchangeably in this thesis.

2. Materials and methods

2.1. Farming in Scania

Scania covers only 2.5 percent of the land area of Sweden, but has 17 percent of the arable land (Statistics Sweden, 2020). Here, nearly 40 percent of Sweden's table potatoes are grown, 30 percent of the winter wheat, 50 percent of the rapeseed and 96 percent of the sugar beets harvested in the country. Regarding horticulture, 53 percent of the greenhouse area and 63 percent of the outdoor cultivation area is located in Scania, delivering nearly 70 percent of the harvest (The County Administrative Board of Scania, 2016).

Compared to Sweden as a whole, a larger proportion of Scanian farm enterprises are involved in crop production (including horticulture), a smaller proportion are focused on animal husbandry, and farms classified as smallholdings are fewer than the national average (Statistics Sweden, 2020). The share of farming certified as organic is lower than in the country as a whole, with between one fourth (nitrogen and phosphorus) and one third (potassium) of the mineral fertilizers and more than half of the pesticides used in Sweden ending up on Scanian farms.

There are variations within the province, with fertile plains dominated by calcareous clay moraine in the southwestern parts and forested areas on moraine of primary rock in the northeast (Dänhardt et al., 2013). The proportion of arable land varies between 84 percent in the municipality of Staffanstorp and 7 percent in Osby (Johansson et al., 2014). In the forested areas along the northern border up to 94 percent of the arable land is devoted to cultivation of ley.

Regional differences in farm specialization have been described by dividing the province into five farming areas (Johansson et al., 2014):

1. The plains with specialized crop production. Here, in the southwestern parts of the province, harvests are high and much of the arable land is devoted to cultivation of cereals, sugar beets, oil crops and vegetables.

2. The plains with mixed farming, further inland and along the southeastern coast. Around half of the farming enterprises focus on crop production, the

other half on animal husbandry. Many of the crop producers specialize in horticultural products.

3. The middle area, in the eastern parts and to the far northwest, has considerable production of milk and pork. Cereal yields are lower than in the plains, but ley yields are high.
4. The mixed farming area, in the central parts, where a majority of farms focus on production of milk and beef. Most of the arable land is used for ley production.
5. The forested area, along the northern border, where conditions are unfavourable for crop production. Ley is grown on 90 percent of the arable land, which in turn covers only around 5 percent of the total area. Milk and beef dominate agricultural production, but forestry is more prominent.

During the last century, Scania has mirrored the general trend in European agriculture with increasingly mechanised and intensified cropping systems (Dänhardt et al., 2013). Increased use of mineral fertilizers and chemical plant protection has contributed to an increase in production, but the agricultural landscape has undergone a fundamental change and is now more uniform with fewer elements of natural habitats than it was a hundred years ago.

While Scania has the largest number of plant and animal species of all Swedish regions, it has also suffered the greatest loss of species (The County Administrative Board of Scania, 2016), especially in the agricultural areas. An increasingly uniform landscape with fragmented natural habitats prevents mobility and spreading. A decline in profitability has led to a decrease in traditional management of meadows and pastures, which in turn has resulted in significant loss of these species-rich habitats.

Eutrophication remains a problem in Scania, with adverse effects on aquatic ecosystems (The County Administrative Board of Scania, 2017). Leaching from agricultural land is a major contributor of nutrients in watercourses and coastal waters.

Plant protection substances, mainly herbicides, have been found in 80 percent of surface water samples, and one third of groundwater samples contain traces of pesticides that have been prohibited for many years (The County Administrative Board of Scania, 2017; Rabow, 2017). Findings of pesticides are more common in samples from agricultural areas than from areas with other types of land use.

2.2. Quantitative data on farm enterprises

Quantitative data on farm enterprises in Scania was analysed to explore the current prevalence of integrated crop rotations. The SAM application is a yearly application for farm subsidies submitted by farmers to the Swedish Board of Agriculture (Swedish Board of Agriculture, 2022b). It includes reports on what crops the applicants (i.e. farm enterprises) plan to grow in each of their parcels of land during that year. Data on Scanian farms, based on the SAM applications for the year 2020, was provided by the Swedish Board of Agriculture. The data includes names and addresses of the farm enterprises, and the crop codes and area (in hectares) for each farm parcel.

As the data file covers a large majority of Scanian farm enterprises, this data can be described as a census[2] rather than a sample. Thus, the analysis is presented as descriptive statistics. Microsoft Excel was used for data processing.

The crop codes used by the Swedish Board of Agriculture were re-coded into three categories:

- Arable (A),
- Horticultural (H), and
- Other (O).

A full list of crop codes is included in Appendix 1. Crops categorized as 'A' are for example grains, oil crops, sugar beets and ley; crops categorized as 'H' are vegetables, soft fruit and herbs. Production on non-arable land is classified as 'Other', together with perennial cultures and crops that are neither agricultural nor horticultural.

The code for 'Soft fruit, other' includes both crops that can be part of a crop rotation (e.g. raspberries and currants) and those that are permanent such as vineyards. In this study, 'Soft fruit, other' has been classified as 'H'.

Potatoes are sometimes considered an arable crop, sometimes horticultural. To account for both perspectives, data was processed in two ways: with 'table potatoes' categorized as 'A', and as 'H', respectively.

The geographical locations of farm enterprises were coded with the numbers 1–5, representing the five farming areas. In cases where a geographical name refers to an area that spans more than one municipality, the address is assumed to be located in the municipality where the main village or town with that name is situated. Farm enterprises with an address outside Scania (i.e. where the farming takes place in Scania, but the mailing address of the company is elsewhere) were coded as '0'.

[2] When everyone in the population is 'sampled', the resulting sample is called a census (De Veaux et al., 2015). While a sample statistic can be used to estimate a population parameter, the result of a census actually *is* the population parameter.

The total number of hectares farmed by each applicant was calculated.

The number of farm enterprises growing arable, horticultural, and other crops, and combinations of these categories, was determined, including how the distribution of the categories differs between farming areas and based on farm size.

2.3. Survey

A web-based questionnaire, combining quantitative and qualitative methods, was constructed and administered to farmers in the study area. The online tool Netigate was used as a platform for the survey.

The first part of the questionnaire (Appendix 2) consists of background questions covering demographic factors, geographical location, farm size, cropping system and soil type. The type of crops grown by the respondent is covered by a multiple-choice question where he/she is asked to choose all that apply from a list of crop categories. The final section contains questions about subjective attitudes and perceptions regarding integrated crop rotations and farm decision making. Open-ended questions are included, but are mostly optional, designed to allow respondents to add comments and clarifications to the other questions.

Before distribution, the questionnaire was tested by two persons connected to SLU and one farmer to ensure that the phrasing and structure of the questions were intelligible and unambiguous to the intended respondents (Dörnyei & Taguchi, 2010).

The questionnaire was distributed to farmers in Scania during April and May 2021 with the help of the Federation of Swedish Farmers (LRF) and the Swedish Organic Farmers Association (Ekologiska lantbrukarna), reaching more than 7 500 potential respondents. A link to the questionnaire was also posted in two Facebook-groups: Ekologiska bönder [Organic farmers] and Småbrukare och framtidens lantbrukare [Smallholders and farmers of the future] and distributed to the personal network of a former organic farmer (now a student at SLU), with the request that these persons would in turn recruit additional respondents among their acquaintances, so-called snowball sampling (De Veaux et al., 2015).

Due to the nature of the data obtained from the survey (categorical and ordinal), non-parametric methods were employed. Microsoft Excel, Minitab, and SPSS were used for the analysis.

The Kruskal-Wallis test was used to determine whether statistically significant differences existed between the rating of different factors in the questions pertaining to attitudes and perceptions. Post-hoc analysis using the Dunn's test (Dinno, 2015), with a significance level of $\alpha=0.05$, was then performed to determine between which specific factors the significant differences lay. To compensate for the risk of type I errors (i.e. the risk of erroneously rejecting the null hypothesis) associated with multiple comparisons, the significance level was

adjusted using the Bonferroni correction method[3]. In order to ascertain whether farmers with an integrated crop rotation and farmers with an arable rotation differed in their rating of the factors, pairwise comparisons (factor by factor) were carried out using the Mann-Whitney test.

The responses to the optional open-ended questions were analysed through a process of content analysis. For further description of this method, see section 2.4.3 on qualitative analysis of interviews. In the results of the content analysis, the respondents are referred to as 'R' (for respondent) and a number based on the order in which they completed the questionnaire.

2.4. Interviews

> "Semi structured interviews allow respondents the chance to be the experts and to inform the research." (Leech, 2002, p. 668)

The semi structured interview is a research method characterized by a combination of structure, in the form of a pre-determined interview guide, and flexibility, with respect to the participants freely responding to open-ended questions and the researcher being able to probe the responses by posing follow-up questions (McIntosh & Morse, 2015; Longhurst, 2003). In this study, the interviews provide a qualitative approach to exploring the experiences of farmers.

2.4.1. Selection of participants

Participants were selected through a process of variable purposive sampling. The aim of the sampling process was to cover three categories of farmers, namely those that include both arable and horticultural crops in their crop sequences, and those that grow exclusively arable or horticultural crops, respectively.

The selection criteria for farmers including both crop types and farmers specializing in arable crops were a farm size of 20–100 ha (chosen to represent a medium size (Swedish Board of Agriculture, 2021a)), and a minimum of 1 ha horticultural crops for farmers growing both crop types. As horticultural producers generally operate on a smaller scale (Swedish Board of Agriculture, 2021a) and as the number of farmers producing exclusively horticultural crops is small, no specific criteria regarding farm size were established for that category.

To minimize the influence of confounding factors stemming from differences in climate etc., the aim was to limit the selection to farmers in areas 1 and 2 (see

[3] When a comparison involves n null hypotheses, the Bonferroni correction is used to maintain the overall α level by comparing the p of each test with α/n instead of α (Aickin & Gensler, 1996).

section 2.1 above), specifically Southwestern Scania.[4] Due to difficulties in recruiting farmers with exclusively horticultural crop rotations, one participant operating in farming area 3 was included on the final list.

Based on the SAM data files, a number of potential participants were identified and approached. A final list of eight participants was established. The selected participants are between 33 and 69 years old, six men and two women. Their farm size varies from 4 to 100 ha, with an average of 57 ha. Their farms are located in the municipalities of Eslöv (1 farm), Lund (2), Lomma (2), Vellinge (2) and Båstad (1). In the text, the farmers are referred to as 'P' (for participant) and a number from 1 to 8, based on the order in which they were interviewed. P1–3 grow arable crops, P4–6 have integrated crop rotations, and P7–8 grow horticultural crops.

2.4.2. Data collection

The interviews were conducted and recorded in November and December 2021, seven via telephone, one (at the initiative of the participant in question) in a face-to-face meeting. Before the interviews all participants were presented with a document containing information on the purpose of the study and the terms of participation (Appendix 3). They were asked to give their consent via e-mail or verbally in the audio recording.

The interview guide (Appendix 4) was designed to explore the following:

- The participants' attitudes and perceptions regarding crop sequences that include both arable and horticultural crops,
- the factors determining decisions regarding crop sequences, and
- the reasoning behind their choice of integrating arable and horticultural crops or not.

A number of background questions to provide context were included.

Audio recording and word-for-word transcription of interviews is standard procedure in interview research (Kvale & Brinkmann, 2014; McIntosh & Morse, 2015). The degree to which the transcript should reflect different aspects of the verbal communication, e.g. pauses, repetitions, emotional expressions etc., must be decided based on the research theme and method (Kvale & Brinkmann, 2014). For the purpose of this study, the transcript is verbatim and remains true to the spoken language, but no special notation is used for other aspects of the communication.

[4] Southwestern Scania is defined here as the municipalities of Landskrona, Kävlinge, Eslöv, Lomma, Burlöv, Staffanstorp, Lund, Malmö, Svedala, Vellinge, Trelleborg and Skurup.

2.4.3. Qualitative analysis of interviews

The interviews were analysed through a process of qualitative content analysis with an inductive approach. Content analysis is a method for interpretation of text data through a systematic process of coding and classification of themes or patterns (Hsieh & Shannon, 2005). An inductive approach starts with observations and the research findings emerge from the data, in contrast to deductive research which takes its departure from existing theories and uses data to test those theories (Thomas, 2003; Elo & Kyngäs, 2008).

Qualitative content analysis, with roots in social research (Bengtsson, 2016), is widely used in nursing and education research (Graneheim & Lundman, 2004), but it is not linked to any particular science (Bengtsson, 2016). It was chosen as it offers a systematic and structured tool with which to analyse the manifest, literal content of the interviews, but also allows for an interpretative exploration of the underlying or latent meaning (Graneheim & Lundman, 2004).

The analysis is based on the process outlined by Graneheim & Lundman (2004) and started with a thorough reading of the material. The text was sorted into content areas, corresponding to topic areas in the interview guide:

1. *Factors in decision making*, concerning the underlying priorities in farm decision making
2. *Perception of and opinion on integrated crop rotations*
3. *Choice of crop rotation* – the motivations behind the participants' choice of integrated/specialized rotations and their assessment of the practical consequences of that choice
4. *Preconditions for change*

While the four content areas were analysed separately, in the results section the first and third areas are presented together as the responses are closely interrelated.

Sections of the text pertinent to the research questions were extracted. These so-called meaning units were condensed, i.e. shortened but with the core content preserved. Each condensed meaning unit was labelled with a code.

The interviews having been conducted in Swedish, the transcripts are also in Swedish. During analysis, the condensed meaning units were translated, and the coding process was from there on conducted in English.

The codes were compared and grouped into categories and subcategories, constituting the manifest content of the text, and reflecting the central messages of the data. The number of participants contributing to each category was recorded and is presented to illustrate the hierarchical relation between categories (Bengtsson, 2016). The author’s interpretation of the latent content was formulated into themes. An example of the coding process is included in Appendix 5.

Quotes that illustrate the themes and categories were identified and translated from Swedish to English, with the aim to convey the contextual meaning of the original. Thus, while attempting to stay as close as possible to the original, in some cases idiomatic expressions were interpreted rather than translated word-for-word, and the syntax was corrected when needed. To improve readability, punctuation was added and filler words – such as ”er”, ”um” – were omitted. In cases where sections of the original transcript were deleted, […] was inserted to mark the omission.

3. Results

3.1. Quantitative data on farm enterprises

The material contains data on 7249 farm enterprises. The large majority have a crop mixture of 'arable' (A) and 'other' (O), and very few grow exclusively 'horticultural' (H) or a combination of 'horticultural' and 'other'. When table potatoes are categorized as an arable crop, 502 farm enterprises, or 6.9 percent, produce a combination of arable and horticultural crops (AH and AHO) (Figure 2a). However, with table potatoes categorized as a horticultural crop, 724 farm enterprises, or 10.0 percent, produce both types of crops (Figure 2b).

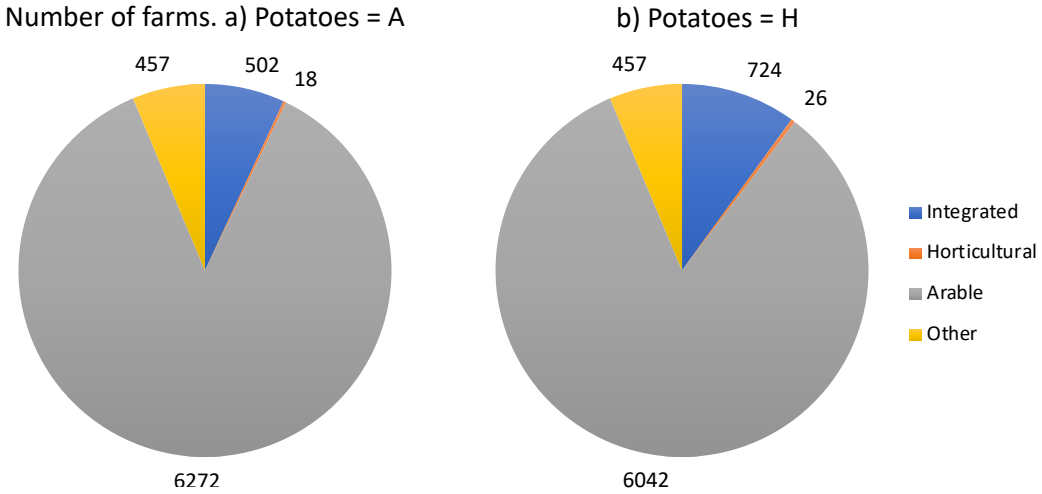

Figure 2a and 2b. Number of farm enterprises with different crop rotations: Integrated (AH and AHO), Horticultural (H and HO), Arable (A and AO) and Other (O). Results when potatoes are categorized as arable (a) and horticultural (b).

The farm enterprises are distributed across the five farming areas (Tables 1 and 2). A chi-square test confirms an association between farming area and choice of crop rotation ($\chi 2$=158.1, p<0.001 with table potatoes as A; $\chi 2$=155.7, p<0.001 with table potatoes as H). Farms with both arable and horticultural production are more numerous in the plains with specialized crop production and in the middle area (areas 1 and 3), with fewer farms in the mixed farming area and the forested area

(areas 4 and 5). The 'Arable' (A+AO) category is proportionally distributed across the farming areas, although with a slightly higher presence in area 4. 'Horticultural' (H+HO) farms are almost exclusively present in areas 1–3. The 'Other' (O) category has a low presence in area 1 but is more abundant in area 5 and among farm enterprises with an address outside Scania ('0'). The results are similar when potatoes are categorized as a horticultural crop.

*Table 1. Distribution of farm enterprises by farming area and crop rotation, with table potatoes categorized as an arable crop. The crop rotation categories are: Integrated (farms producing both arable and horticultural crops, i.e. AH and AHO), Horticultural (H and HO), Arable (A and AO) and Other (O). The percentage that each cell constitutes of its row is presented in parentheses. *'0' = companies with a mailing address outside Scania.*

Farming area	Integrated	Horticultural	Arable	Other	Total
1	115 (12.5)	4 (0.4)	769 (83.4)	34 (3.7)	922
2	118 (5.9)	6 (0.3)	1752 (87.5)	127 (6.3)	2003
3	205 (9.2)	7 (0.3)	1876 (84.2)	140 (6.3)	2228
4	56 (3.4)	1 (0.1)	1499 (90.5)	101 (6.1)	1657
5	5 (1.5)	0 (0.0)	299 (86.9)	40 (11.6)	344
0*	3 (3.2)	0 (0.0)	77 (81.1)	15 (15.8)	95
Total	502 (6.9)	18 (0.2)	6272 (86.5)	457 (6.3)	7249

*Table 2. Distribution of farm enterprises by farming area and crop rotation, with table potatoes categorized as a horticultural crop. The crop rotation categories are: Integrated ((farms producing both arable and horticultural crops, i.e. AH and AHO), Horticultural (H and HO), Arable (A and AO) and Other (O). The percentage that each cell constitutes of its row is presented in parentheses. *'0' = companies with a mailing address outside Scania.*

Farming area	Integrated	Horticultural	Arable	Other	Total
1	139 (15.1)	5 (0.5)	744 (80.7)	34 (3.7)	922
2	184 (9.2)	7 (0.3)	1685 (84.1)	127 (6.3)	2003
3	292 (13.1)	13 (0.6)	1783 (80.0)	140 (6.3)	2228
4	94 (5.7)	1 (0.1)	1461 (88.2)	101 (6.1)	1657
5	9 (2.6)	0 (0.0)	295 (85.8)	40 (11.6)	344
0*	6 (6.3)	0 (0.0)	74 (77.9)	15 (15.8)	95
Total	724 (10.0)	26 (0.4)	6042 (83.3)	457 (6.3)	7249

The enterprises are grouped into three categories based on farm size: <20 ha, 20–100 ha, and >100 ha (Tables 3 and 4). A chi-square test confirms an association between farm size and choice of crop rotation ($\chi 2$=526.1, p<0.001 with table potatoes as A; $\chi 2$=647.2, p<0.001 with table potatoes as H). Farmers that include both arable and horticultural crops are proportionally numerous among farms of >100 ha, while they are proportionally few among farms of <20 ha. The opposite is true for the 'Other' category, which is also generally unevenly distributed across the farm size categories. 'Horticultural' is absent among the largest farms, while

the ‘Arable’ category is more evenly distributed. The relative distribution is similar, regardless of how potatoes are categorized.

Table 3. Distribution of farm enterprises by farm size and crop rotation, with table potatoes categorized as an arable crop. The crop rotation categories are: Integrated ((farms producing both arable and horticultural crops, i.e. AH and AHO), Horticultural (H and HO), Arable (A and AO) and Other (O). The percentage that each cell constitutes of its row is presented in parentheses.

Farm size	Integrated	Horticultural	Arable	Other	Total
<20 ha	116 (3.3)	11 (0.3)	2973 (84.7)	412 (11.7)	3512
20–100 ha	190 (7.8)	7 (0.3)	2203 (90.2)	42 (1.7)	2442
>100 ha	196 (15.1)	0 (0.0)	1096 (84.6)	3 (0.2)	1295
Total	502 (6.9)	18 (0.2)	6272 (86.5)	457 (6.3)	7249

Table 4. Distribution of farm enterprises by farm size and crop rotation, with table potatoes categorized as a horticultural crop. The crop rotation categories are: Integrated ((farms producing both arable and horticultural crops, i.e. AH and AHO), Horticultural (H and HO), Arable (A and AO) and Other (O). The percentage that each cell constitutes of its row is presented in parentheses.

Farm size	Integrated	Horticultural	Arable	Other	Total
<20 ha	154 (4.4)	18 (0.5)	2928 (83.4)	412 (11.7)	3512
20–100 ha	282 (11.5)	8 (0.3)	2110 (86.4)	42 (1.7)	2442
>100 ha	288 (22.2)	0 (0.0)	1004 (77.5)	3 (0.2)	1295
Total	724 (10.0)	26 (0.4)	6042 (83.3)	457 (6.3)	7249

3.2. Survey

The online survey yielded 24 responses. Three incomplete responses were discarded, leaving 21 valid responses. The shortest reply time was three minutes and 36 seconds, to be compared with the expected five to ten minutes. Six responses have a reply time between four and five minutes. Despite the short response time, the 21 responses were considered sincere and were all included in the final sample.

Due to the low response rate, the number of respondents in each category is insufficient for analysis of correlation between choice of crop rotation and factors such as farm size, farming area, organic/conventional etc. The statistical analysis of the survey is therefore limited to the questions about subjective perceptions and attitudes.

3.2.1. The respondents

The final set of respondents consists of two women, 18 men and one ‘other’, with a median age of 54 years. The size of farms ranges from 19 to 950 ha, with a mean size of 164 ha and a median of 100 ha.

Six respondents include both arable and horticultural crops in their rotation. All of these grow vegetables, while none of them include soft fruit or ornamental plants.

This group is hereafter referred to as 'AH', while farmers growing exclusively arable crops are referred to as 'A'.

All respondents except one include cereals in their rotation.

The respondents were asked whether they will continue to practice the same type of crop rotation, i.e. either A or AH. All six farmers belonging to the AH category stated that they definitely or probably would continue, while the responses from the farmers in the A category were more varied (Figure 3).

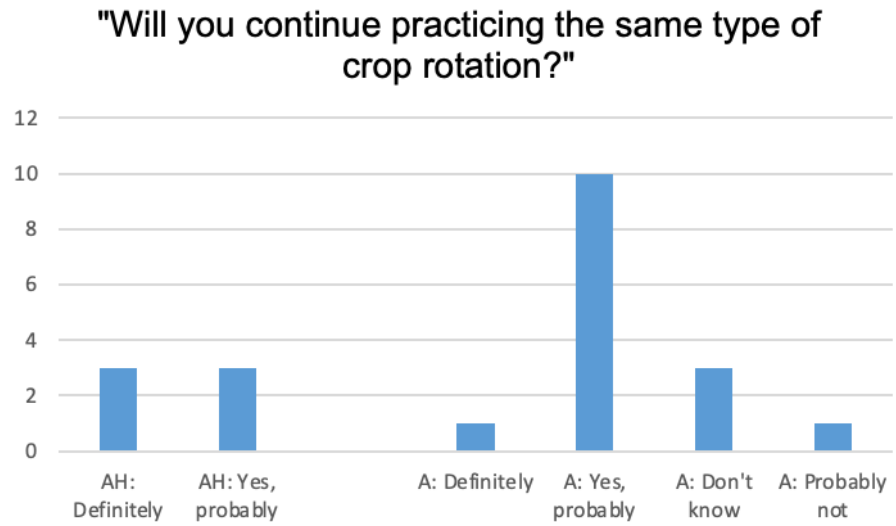

Figure 3. Responses to the question: Will you continue practicing the same type of crop rotation? Respondents in the AH and A categories are presented separately. Respondents were asked to select the appropriate response among the alternatives 'Definitely', 'Yes, probably', 'Don't know', 'Probably not' and 'Definitely not'. The bars represent the number of respondents selecting each alternative.

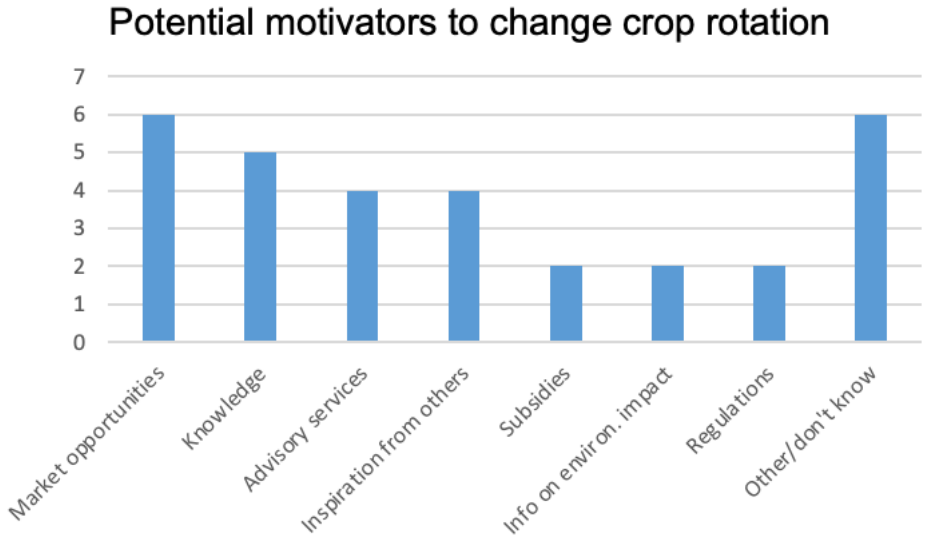

Figure 4. Potential motivators for farmers in the A category to include horticultural crops. Respondents were asked to select a maximum of three alternatives. The bars represent the number of respondents selecting each alternative.

Respondents in the A category were asked an additional question: “What would be needed for you to choose to include horticultural crops in your crop rotation?” ‘Better market opportunities’ was selected by the highest number of respondents, followed by ‘More knowledge’ (Figure 4).

3.2.2. Attitudes and perceptions

Three matrix questions were designed to explore the attitudes and perceptions of the respondents regarding crop rotations and decision making. The findings suggest that economic considerations and the physical characteristics of the farm have the largest influence on decisions on crop rotation, together with the personal interest of the farmer, and that decisions are influenced by what is compatible with the existing cropping system and/or farm equipment. An integrated crop rotation, with both arable and horticultural crops, is believed to have a positive effect on profitability, biodiversity and spreading of risk.

Factors influencing decision making

The question “How important are the following factors when you decide what to grow on your farm?” has a rating scale ranging from 1 (‘No importance’) to 5 (‘Decisive importance’).

A Kruskal-Wallis test showed that there was a statistically significant difference in median rating between the factors ($H(4) = 64.36$, $p<0.001$). Post-hoc analysis using Dunn’s test with a significance level of 0.05 showed that ‘physical characteristics of the farm’ and ‘economic factors’ received the highest ratings, significantly higher than ‘environmental’ and ‘social’ factors but not significantly higher than ‘practical’ (Table 5). ‘Social factors’ received the lowest ratings, with a significantly lower median than all other factors. The full results of the post-hoc analysis is included in Appendix 6.

Pairwise comparison, factor by factor, of how the two categories of farmers rated the importance of the factors did not yield any significant results.

Table 5. Rating of factors influencing choice of crops. Data presented as medians with different letters indicating significant differences between factors, and the mean rank of factors provided by the Kruskal-Wallis test. α=0.05.

Factor affecting decision	Median	Mean rank
Physical characteristics of the farm	5 a	79,3
Economic factors	5 a	71,5
Practical factors	4 ab	58,1
Environmental factors	3 b	41,1
Social factors	1 c	14,9
Overall		53,0

Effects of integrating arable and horticultural crops

The next matrix question, "What will, in your opinion, be the effect of including both arable and horticultural crops in the rotation? Mark how you think the following aspects will be influenced", is rated from 1 ('Very negative') via 3 ('Neutral/not relevant') to 5 ('Very positive').

The medians of the ratings of the different factors are not equal ($H(9) = 37.24$, $p<0.001$), but there are few statistically significant differences (Table 6). Dunn's test ($\alpha=0.05$, Appendix 6) showed that the effect of an integrated crop rotation on 'profitability' was rated as significantly more positive than the effect on 'eutrophication', 'workload', 'spread of toxic substances' and 'yield stability'. Although not significant, 'workload' was perceived as slightly negatively influenced.

Table 6. Perceived effect of an integrated crop sequence on the included factors. Data presented as medians with different letters indicating significant differences between factors, and the mean rank of factors provided by the Kruskal-Wallis test. α=0.05.

Affected factor	Median	Mean rank
Profitability	4 a	148,3
Biodiversity	4 ab	131,1
Spreading of risk	4 ab	130,6
Plant protection	3 ab	112,8
Soil health	3 ab	109,6
Climate	3 ab	99,8
Eutrophication	3 b	86,6
Workload	2 b	82,1
Spread of toxic substances	3 b	78,1
Yield stability	3 b	76,0
Overall		105,5

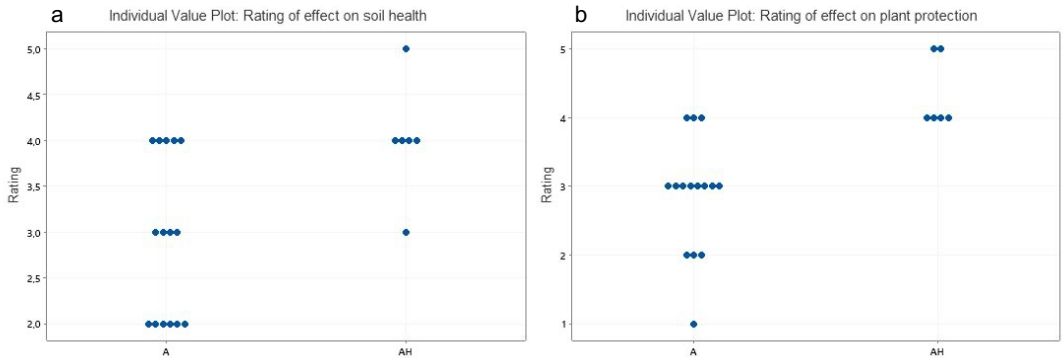

Figure 5a and 5b. Rating of the effect of an integrated crop rotation on soil health (a) and plant protection (b), A and AH presented separately.

Pairwise comparisons using the Mann-Whitney test showed that AH respondents have a significantly stronger belief than A respondents in the positive effects of an

integrated crop rotation on soil health (median rating 4 and 3, respectively, $p<0.05$) (Figure 5a) and plant protection (median rating 4 and 3, respectively, $p<0.005$) (Figure 5b), whereas no significant difference can be demonstrated in the rating of the other factors.

Factors influencing the choice of integration vs. specialization

"How have the following factors influenced your decision to specialize in arable crops/include both arable and horticultural crops in your crop rotation?" This question has a rating scale for the level of influence ranging from 1 ('Very negative') via 3 ('Neutral/not relevant) to 5 ('Very positive').

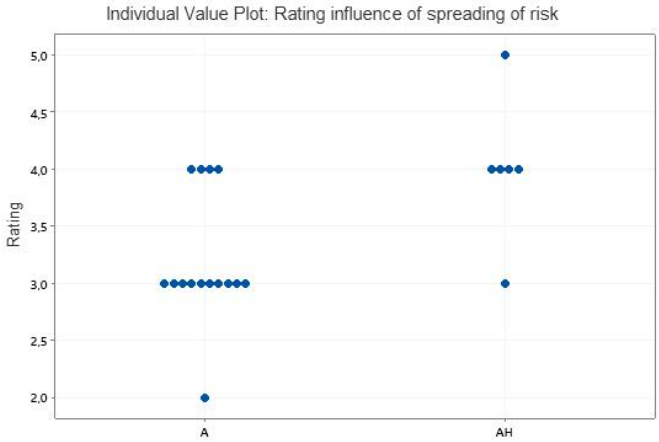

Figure 6. Rating of the influence of spreading of risk on choice of crop rotation, A and AH presented separately.

The medians of the responses are not equal ($H(8) = 41.96$, $p<0.001$), but there are, again, few significant differences between factors (Table 7). Dunn's test ($\alpha=0.05$, Appendix 6) showed that the influence of 'physical characteristics of the farm' and 'personal interest' was rated as significantly more positive than that of 'environmental considerations', 'habit' and 'access to advisory services'. 'Fits cropping system/machinery' was rated significantly higher than 'habit' and 'access to advisory services'.

Table 7. Rating of factors influencing the respondents' choice of either an integrated crop sequence or specialization. Data presented as medians with different letters indicating significant differences between factors, and the mean rank of factors provided by the Kruskal-Wallis test. α=0.05.

Factor affecting decision	Median	Mean rank
Physical characteristics of the farm	4 a	126,5
Personal interest	4 a	123,0
Fits cropping system/machinery	4 ab	117,8
Economic factors	4 abc	114,7
Spreading of risk	3 abc	88,5
Workload	3 abc	83,8
Environmental considerations	3 bc	68,8
Habit	3 c	66,6
Access to advisory services	3 c	65,3
Overall		95,0

No significant difference between A and AH in the rating of the influence of individual factors can be demonstrated except regarding ‘spreading of risk’, where pairwise comparison shows that the AH respondents report a significantly more positive influence than A (median 4 and 3, respectively, $p<0.05$) (Figure 6).

3.2.3. Content analysis of free text answers

Ten respondents have provided free text answers, to five different questions. One person responded to four open-ended questions, five responded to two and four responded to one.

The questions were open-ended but were all formulated as an opportunity for the respondents to add their own comments to the topic of the preceding question.

Four categories were identified. ‘Economic sustainability’, together with ‘Characteristics of the farm’ (covered by six and five respondents, respectively), are front and centre among responses – regarding both attitudes towards integrated crop rotations and farmers’ decision making processes. ‘Practical considerations’ and ‘Social and emotional factors’ feature to a lesser degree.

Economic sustainability

Economic concerns are mainly mentioned in the context of limitations – difficulties to obtain sales channels and achieve profitability, initial costs of starting vegetable farming, and insecurity. One respondent believes that including vegetables in the rotation has the potential to increase profitability but cautions that there is a risk of negative returns in “bad years” due to lower yield stability. Improved economic potential is mentioned as a potential motivator to including horticultural products in the crop rotation.

Vegetable farming is considered by one respondent to be associated with higher risk than growing arable crops. Two respondents express a wish to diversify their crop sequences, but lack of certainty regarding marketing of products is an obstacle: “Thinking about vegetables, what I need to check is guarantee for sales and marketing channels.” (R1)

Characteristics of the farm

While economic concerns are depicted as something that may fluctuate, change, or be subject to insecurity, the physical characteristics of the farm are depicted as definitive determinants in the context of crop rotation decisions. Limitations rather than opportunities are mentioned in connection with this category, as in this quote by R17: “This response refers to a hypothetical example that I should start growing some kind of horticultural crop on my rather stiff soils, which would be downright inappropriate.”

Three respondents describe that the soil type (i.e. clay) of their farm is unsuitable for vegetable farming, one of them adding that a cold microclimate further prevents

the inclusion of horticultural crops. On a similar note, one respondent states that their choice of crop is limited by a high occurrence of wildlife.

The geographical location of the farm in relation to marketing channels is mentioned by one respondent as having had a positive influence on the decision to include both arable and horticultural crops in their crop rotation.

Practical considerations

Several respondents mention practical considerations to be taken into account before starting vegetable farming: the need for a certain volume in order to be profitable, and the time and resources that need to be invested. In the words of R1: "There are costs in terms of both time and liquidity involved in starting for example vegetable production." A concrete agronomic need – access to irrigation – was mentioned by one respondent as necessary for them to take the step to diversify their crop rotation.

Social and emotional factors

Without further elucidation, one respondent points out social and professional considerations as factors in the decision to specialize in arable crops. One respondent describes vegetable farming as essentially different from grain production:

> Vegetable farming is so different from my grain production that it is like a completely different line of business. If I wanted to enter a new field, there are other things that seem more interesting to me. (R17)

3.3. Interviews

> If I find a suitable vegetable culture, or a vegetable that fits, then I'm ready to set aside a hectare or so initially just to try and see, ok, does this work. And also, well, I mean, if the plant lice eat it, then, well it was just a hectare, it wasn't like fifteen or twelve hectares or so. (P2)

The analysis of the interviews resulted in four themes and twelve categories. The themes are: 'Achieving economic sustainability', 'Feasibility – practical concerns in relation to pre-existing conditions', 'The farm in a bigger context' and 'Personal motivation and abilities'. Comments on whether integrated crop rotations are new or not constitute a category of their own and are presented under 3.3.1 below. The themes and categories are illustrated in Figure 7. A full presentation in table form of the categories and subcategories identified in each content area is included in Appendix 7.

Achieving economic sustainability

Feasibility – practical concerns in relation to pre-existing conditions				
Characteristics of the farm	Workload and crop choice	Crop protection	Optimizing the crop rotation	Farm infrastructure

The farm in a bigger context			
The farm in relation to environmental issues	Effects on soil health	Network and support	Societal factors

Personal motivation and abilities	
Knowledge and information	Motivation and emotion

Figure 7. The themes (in bold) and categories identified in the data set.

As well as being a major category itself in each of the content areas, 'Achieving economic sustainability' can be found as a motivating factor in most of the categories. It deals with opportunities as well as risk, making a profit as well as avoiding losing money.

'Feasibility – practical concerns in relation to pre-existing conditions' is about choosing crops and management practices based on what is possible due to the characteristics and capacity of the farm and the farmer and based on what is necessary to produce a decent yield.

'The farm in a bigger context' relates to the environmental and social context in which the farmer operates. Farming will inevitably affect the environment and the place where it is undertaken, but farmers are also affected by their surroundings.

'Personal motivation and abilities' deal with the psychological, emotional, and cognitive traits and experiences of the farmer.

After this short description of the themes, the categories and themes are addressed in the context of the content areas. While the themes are presented as headings, the categories are highlighted in bold to facilitate reading.

3.3.1. Perception of and opinion on integrated crop rotations

> It's not a new way of thinking but maybe it's a new way of thinking in these modern enterprises so to speak. […] But it's not a new way to think about farming, not in my opinion anyway. (P8)

In response to the question: "Are integrated rotations something new, or old and commonplace?", with slightly different angles, the five participants who voiced an opinion on the subject feel that crop rotations including both arable and horticultural crops is not something new. P2 argues that whether integrated rotations are a self-evident component of cropping systems depends on geographical location:

> I think you could find rapeseed fields stretching almost all the way from Lund down to Kävlinge river. There is nothing else. So, they don't have that tradition, I think people would raise their eyebrows if someone started growing vegetables here. (P2)

In some areas there is a tradition, and thus an infrastructure and a network of buyers. In other areas there is no tradition, and it would cause surprise if someone started growing vegetables. P5 holds the same opinion.

The traditional, self-sufficient farms with livestock, ley, grains, and vegetables is the image P8 uses to illustrate that integrated crop rotations don't amount to a new way to think about farming. But it might be a new way to think in modern enterprises, many of which are highly specialized in either arable or horticultural production and growing a limited number of crops (or even monocultures).

P3 also agrees that integrated rotations are nothing new, but in his opinion, they are increasingly rare. What is new is the tendency of vegetable producers to specialize – because of the high investments required for a successful vegetable production, as buyers' demands and delivery requirements are so high.

P6 describes a shift in crop choices in his area, as farmers are moving away from grains (due to sinking profitability) and large vegetable producers taking over more and more of the land.

P2 points to the fact that imported produce to a high degree has replaced domestic in the processing industry, which has led to a decline in vegetable farming in some areas.

When it comes to the advantages and disadvantages associated with integrated crop rotations, the responses are centred around economic factors, workload, crop protection and environmental issues. In most cases the participants' reasoning amounts to a comparison between horticultural and arable crops, rather than an assessment of crop rotations including both.

Achieving economic sustainability

> If we had stuck to traditional arable crops, that would have been significantly less profitable. In that case I wouldn't have been able to employ people on 60 hectares. I wouldn't have full time employment myself. That's one way to put it. (P5)

Whether in terms of price, margins or profitability, the participants agree that an integrated crop rotation (sometimes expressed in terms of vegetables or horticultural crops) brings with it the chance of a better economic result than a rotation with only arable crops. "One advantage is that you get paid more for horticultural crops and there is quite a big demand", says P1, while P4 emphasizes the fact that horticultural crops are more labour-intensive: "It isn't the crop itself but all the work you put in that you get paid for." On the other hand, the higher inputs needed for vegetable farming are also mentioned.

> Horticultural crops, you can say there's a really high risk, I mean the inputs are high, there's a lot of management. Well, like this summer with the lettuce, like, when you can't get anything from those seedlings you have bought, that's a pretty big loss. (P8)

Two themes can be seen in relation to risk and integrated crop rotations. On the one hand, several participants note that a high variety of crops results in a spreading of risk. P2, for instance, believes that including horticultural crops would entail a wider variety of choices and consequently an opportunity to spread the risk. On the other hand, vegetables are portrayed as entailing a higher risk than arable crops, or, in the words of P3: "There's nothing as volatile as vegetables."

Feasibility – practical concerns in relation to pre-existing conditions

The **workload** will be heavier when horticultural crops are included – the participants all agree on that. There is more manual work involved, and a greater need to hire labour. As argued by P1: "You can't have too large areas, because horticultural crops need a lot of handwork so to speak."

However, the increased cost in terms of labour is related to the chance to earn more, P4 points out. Going from an exclusively horticultural to an integrated crop rotation would lessen the workload due to a higher degree of mechanization, says P8, but introducing arable crops would probably mean outsourcing parts of the work, as investing in all the required machinery is not a realistic option.

Crop protection is an area where many of the participants have an opinion.

> Plant protection is really important on both sides [arable and horticultural] because that is what determines if you get a good harvest to sell or not. (P8)

Several participants maintain that your choice of crop rotation is not decisive for the level of plant protection problems – perhaps there are different problems

depending on the type of crops, but plant protection is important regardless. P3, on the other hand, maintains that there are more problems in integrated rotations compared to arable rotations.

However, horticultural production is perceived as more susceptible to weed problems than arable production. Partly because of the nature of the crops, with more open soil in e.g. vegetables making them less competitive compared to e.g. grains, and partly because there is a lack of herbicide options for horticultural production – touching on political issues as this is to some extent due to regulations and restrictions imposed by national and EU authorities. Another reason behind the lack of options is that the field of horticultural production is too small a market for pesticide producers to make the investment in new products interesting from a business perspective:

> Well, the noose is tightening, unfortunately. And it is tightening in the way that, we still have substances, but there are extremes among weeds that may not be a problem in other cultures but maybe in horticulture there are problems. So that, the chemical companies don't find a reason to seek approval for substances that might work because the turnover is too small which means there will never be any money left to pay the Chemicals Agency. And then, the party is over. (P5)

The role of arable crops in weed management is brought up by P7:

> Since we don't use herbicides on our strawberries it would have been hard to keep the clay soil free from weeds if there wasn't conventional arable farming in between to sort of fix the soil a bit. (P7)

Touching on the category of **Optimizing the crop rotation**, P3 claims that the importance of crop rotations and the pre-crop effects of different combinations of crops is exaggerated: "You won't find that some crops fare better or worse, that is a huge delusion." Conversely, P4 points out that crop rotations are equally important regardless of whether you include arable, horticultural or both. P2 emphasizes the importance of considering pre-crop effects when including vegetables in a previously arable crop rotation. However, no opinion on how integrating horticultural and arable crops relates to the possibility to design an optimal crop sequence was expressed in the interviews.

Horticultural crops put higher demands on **farm infrastructure**, as they require more irrigation. "The horticultural crops have the disadvantage of needing water during a time when we're not getting anything from above", says P5. P2 points out that including horticultural crops means you need other types of infrastructure (e.g. storage and cooling) and logistics than if you stick to exclusively arable crops.

The farm in a bigger context

While some participants stress that the **environmental impact** of a crop rotation depends on which crops are included, not only on whether it is integrated or not, P3 maintains that vegetables have more negative effects on the environment than arable crops.

> Well, I hardly want to say it, but … being a vegetable farmer is hell and it's almost impossible not to affect the environment in some way, it's almost impossible. Anyway, it's not kinder to the environment. (P3)

Short cultures, common among horticultural crops, entail plenty of tillage and more intensive fertilization and are associated with more nutrient leaching than longer cultures, says P8. On the other hand, P5 argues that since he can control the development of his horticultural crops, and thereby their nutrient uptake, and that they are fertilized based on soil analyses and plant need rather than an estimate based on average uptake as is the case for grains, there will be less leaching from his vegetable cultures.

Different aspects of **soil health** are mentioned as an area where arable crops are more beneficial than horticultural crops. Less soil cover, more irrigation and more tillage are factors making horticultural crops less favourable.

> P5: When I started here 30 years ago, it was basically only horticultural crops. But we have changed it totally, and removed cultures, just to have as much covered soil as possible. In order to … and we did that pretty much at once.
>
> Interviewer: And that's for the sake of the soil?
>
> P5: Absolutely.

Keeping the soil covered by a crop as much as possible is a reason for P5 to grow more grains, and ley and grains are believed to improve soil health by increasing the organic matter content and/or due to deep root systems:

> Well, I'm thinking that you improve the soil when you include ley or grain, that's how I think from my perspective. I'm thinking that you increase the organic matter content, maybe you get down a bit deeper and that you let it lie for a while. […] Since we have short cultures, you always have … well, you work the soil quite a lot. (P8)

In short, horticultural crops require large inputs and are associated with higher risk than arable crops, but they also come with the promise of greater earnings – thus, integrated crop rotations are perceived as potentially more profitable than rotations with only arable crops. More hands-on management is required in horticulture, making integrated crop rotations more labour-intensive than arable rotations, but less than a purely horticultural production on a farm of the same size. From a practical perspective, horticultural production is more prone to problems with weeds and requires facilities for irrigation, cooling etc.

Soil health is thought to suffer from negative effects of horticultural production and integrating horticultural and arable crops is a way to mitigate those impacts.

Thus, 'Achieving economic sustainability' and 'Feasibility – practical concerns in relation to pre-existing conditions' are prominent themes in the participants' perception of integrated crop rotations. 'The farm in a bigger perspective' also appears, while 'Personal motivation and abilities' is absent from the responses.

3.3.2. Factors in decision making

What factors are most important when you decide what to grow on your farm? Why have you chosen a specialized/integrated crop rotation? What are the tangible consequences of that choice, both positive and negative? The responses to these questions are closely interrelated and are therefore presented together.

Achieving economic sustainability

> […] we have these products, and we can grow them at a price where everyone can make money. And not only I should make money but also the supply chain all the way till the end. Everyone should be interested in buying our products because they make money from it, there is no other reason. That is the driving force. (P5)

Whether in terms of market, costs, income, or profitability, all but one participant state economic factors as paramount in their decision making. The basis for choosing the type of crops to include in one's crop rotation lies predominantly in an assessment of the market and what makes it possible to make a profit. This is true for all three groups of participants, regardless of their current crop mixture.

Being able to sell one's products, in the sense of consumer demand and what can be sold, is quoted by P1: "We have to look at what we can sell […] That's the important thing, if you can't sell it, it's pure loss." A similar opinion is expressed by P6: "It's what is needed and what I can sell", and P8: "Since you are so market-oriented in a way, unfortunately it's basically the market that decides what you grow."

Getting decent earnings is important. In the words of P1: "And then there's the price, the price has to be good." Similar sentiments are expressed by P3: "The income, how much I'm going to make from it. That is really the only thing."

"Well, it's the bottom line. The result", says P2, thus illustrating the overarching objective of making a profit as a motivating factor in choice of crops. P3 explains why he chooses to specialize in arable crops: "I think it gives a relatively decent economy." "It's to get an acceptable profitability", says P6 about his choice of an integrated crop rotation. P8, on the other hand, cites the same motivation in choosing to grow exclusively horticultural crops: "You prefer to go in for what gives a higher yield and that you make a little bit more money from." Strawberries are mentioned by P7 as a crop that can yield a profit also on a small acreage, while

onions are regarded by P5 as the star of his crop rotation, around which other crops and practices are centred, since it results in the highest net earnings.

P5, however, states that while economic concerns are important in decision making, his choice to include both arable and horticultural crops in his crop rotation makes for less profit in the short term than if he had focused exclusively on vegetables. This short-term reduction of revenue is an investment towards a sustainable management of the farm that will continue to provide a harvest in the future:

> Well, because I believe that the land is just a loan, and I want to make it better in the course of the journey. Not the other way around. So, I mean that, in the short term, yes, but in the long term I hope that my reasoning wins. (P5)

One participant, P4, is unwilling to acknowledge that economic concerns are central to their decision making: "No, I wouldn't say that has any major influence. So that, what you can get in economic terms, rather, it's more about how much we have time for."

Risk does not feature prominently in these responses, but is mentioned by one participant in connection with economic opportunities for farmers operating on a smaller scale:

> There is a lot of work and a lot of fiddling [with strawberries] and a lot that can go wrong, but if you have a small area, you have a decent chance of succeeding. (P7)

P1 states that having a wide variety of arable crops is a way to spread the risk.

Feasibility – practical concerns in relation to pre-existing conditions

The **characteristics of the farm** forms a fundament for what is feasible. The geographical location is a decisive factor for P3:

> Where we live, just above the 55th parallel, it's damn suitable mainly for grains. C3-plants that have their main growth season during these really light-intensive months starting in April, May, June, it's really favourable. It's a lot more favourable than a thousand kilometres to the south. (P3)

Soils well suited for grains is another reason why he, and "everyone here in my area, at least between Dalby and Öresund" (P3), focus almost exclusively on cereal crops. The opposite is true for P8, who states soil type as a reason not to grow grains. Soil type can thus entail limitations as well as opportunities regarding crop choice, both at the farm as a whole and in the distribution of cultures within the farm.

> That's the reason we can grow fresh potatoes because I have some parts that are quite light, and the fresh potato works there. But the soils aren't light enough for us to be among the first in the season, unfortunately not. (P5)

The geographical location of the farm affects the climate, which in turn can influence crop choice. The occurrence of wildlife in the area may play a role, as for P6, who operates in an area where a large presence of geese provides an incentive for choosing to grow maize rather than other cereal crops, as geese don't enter the maize fields.

The size of the farm may affect choice of crops. For instance, P7 owns a 20-ha farm and states that this acreage is too small for arable crops to be profitable, while a labour- and capital-intensive crop like strawberries is a suitable choice. P8 sees their lack of land as an obstacle to maintaining an optimal crop rotation – they cannot afford to set aside land for cereals or ley, as that would entail losing valuable opportunities to grow high-value horticultural crops.

The **workload** associated with particular crops or crop types plays a role in decision making. The amount of time at one's disposal is mentioned as a limiting factor on crop choice, and P8 says that lack of manpower affects their choices:

> […] there is always the question whether you'll get people or not, and that's crucial because what we do is very labour intensive, there's really not much that is done by machine, just the potato harvest … so obviously when that gets harder it will definitely affect what you can manage to grow and get people for. (P8)

Another aspect of the choice of crops is how the workload is distributed across the year, with an even distribution thought to be "better and easier" (P5). Having both arable and horticultural crops means that employment is distributed across the year, argues P4: "If you only had arable crops you would need to have animals too, to have something to do the whole year."

Workload is quoted by all three arable farmers as a reason behind their choice. The fact that horticultural crops entail more manual labour motivates P1 – "I'm nearly 63, so … there's a limit to the amount of handwork you can manage" – as well as P3 – "… well, you saw my age, I was born in -55, so I have passed certain ages and I feel that it's time maybe to take it a bit, a bit less intensive". Both P1 and P3 mention that having an integrated crop rotation would require hiring labour to manage. With an arable rotation there is also the possibility to outsource the work if managing the farm should become overwhelming:

> I live in this area with bulk grain production, ok, so there are four to five machine stations just yearning to run my farm, it's no problem. (P2)

Optimizing the crop rotation is important for plant protection and for an optimal yield, states one farmer, and some crops are excluded due to presence of disease.

> Crop rotation is a very big post because if I don't have that under control, I'll get a pretty poor harvest. And I get diseases and I get insects and I get a low yield. (P2)

A crop can be included because it is "needed in the rotation" (P1), e.g. fava bean, which is valuable on an organic farm for its nitrogen fixating properties. Having many cultures makes rotation possible (even without arable crops, P8 points out), and crops may be chosen for their effect on soil health. P5 is motivated to grow grains because of the pre-crop value it imparts to his onion culture – the horticultural crop is a major source of income, but an integrated crop rotation is necessary to optimize conditions.

Crop protection is not a main topic in the responses regarding decision making but is mentioned by some of the participants. P2 talks about choosing healthy varieties that suit the soil type and that can help prevent build-up of pathogens, thereby reducing the need for pesticides. Increasing problems with weeds has led P6 to include more ley. Growing arable crops in the middle of an area where most of your neighbours are bulk producers of arable crops, who don't care about crop rotation and therefore cause a build-up of pests, is a challenge, according to P2:

> There is a terrible amount of slugs just because I have 400 hectares of rapeseed next to my rapeseed field. So, I'm affected by my surroundings, and if all the neighbours grow rapeseed because it pays well, maybe I should grow something else. Because the cost of pest management that they force upon me, since everyone grows it, becomes too high. (P2)

When it comes to **farm infrastructure**, the role of the farm's existing machinery and equipment in choice of crops can be viewed in different ways:

> Since the machinery is really customized for these special things I have now and I don't really have any equipment for cereals, you choose to grow what you have equipment for. (P6)

> No, I mean, I wouldn't say that, because the machines are purchased for the activities we do, not because it just happened that way. There was a thought behind it, so no, you can't say that, it's a thought-out strategy. We don't have a thresher, for example. (P5)

While some participants say that their choice of crops is limited to cultures that fit the equipment they already have, others state that the crop plan comes first and that the machinery is a result of that, not the other way round. A tangible negative aspect of having an integrated crop rotation compared to purely arable mentioned by P4 is that you need more machinery, special equipment for the vegetables. On the other hand, P8 finds that one benefit of specializing in horticultural crops is that you are flexible to choose crops based on demand and on what suits your soils because you haven't invested heavily in machinery specifically for a single crop, or in infrastructure for animal husbandry.

Facilities for irrigation can in part compensate for soil type and make it possible to grow crops that would otherwise not thrive, as mentioned by two participants.

Another practical downside of being a vegetable farmer, making you vulnerable in relation to the market and the demand of buyers, is that many vegetables can't be stored. Instead, they must be harvested, sold, and eaten at just the right time:

> And it's really hard when you deal with living crops when it's like that, I mean the lettuce, if it is ready, it should be harvested and sold then, it can't wait for two weeks, then it will go bad. And maybe that's the advantage of grains, you can thresh it when it's right but then you can dry and store it. (P8)

The farm in a bigger context

> If I were to really think about the environment, then I wouldn't grow anything but grass. And I mean, then we can forget it, but you have to compromise with that. So, we try to have 20 hectares maybe, up to 30 hectares of winter wheat. (P5)

A wish to improve soil health and structure impels P5 to maximize the proportion of grains in their crop rotation. Most of the participants declare a wish to do what is favourable for the environment, but **environmental concerns** do not feature prominently as a motivating factor in choosing what to grow on the farm. The two organic farmers among the participants (P1 and P4) talk about environmental concerns in the context of their choice to exclude pesticides and chemical fertilizers, rather than their choice of crops. Similarly, P6 states that concern for the environment doesn't affect his choice of crops, but that it motivates him to optimize the management of his current crops in terms of fertilization etc.

The exception is P5 who states that concern for **soil health** and structure motivate him to maximize the amount of grain in his rotation, and that a major drawback of horticultural crops is their detrimental effect on the soil (in terms of not contributing to soil organic matter and needing moist soil and therefore leading to the soil being compacted). Having an integrated crop rotation allows him to compensate for some of the negative effect of vegetables:

> But it doesn't help to do it for one year. It doesn't help to have one year of winter wheat, it has to be a number of years with something other than horticultural crops. (P5)

Personal motivation and abilities

Several respondents mention **motivation** based on interest and enjoyment – choosing crops based on what you find interesting and fun, or the excitement of trying something new.

> I'm very, very, I mean childishly, silly or what you want to call it, but, even unexpectedly, interested in grains, so I've thought a lot about it. And that's probably something that I share with many others. I'm very interested. I believe a lot in what I do, of course. (P3)

P1 argues that "If you're not interested in a crop, it doesn't turn out well, because I mean then you don't pay that culture any particular attention so to speak." In explaining why he has increased the share of horticultural crops on his farm, P6 says: "And [it is] a little bit because you find it exciting with a few new things, actually, and trying and developing something new."

The force of habit, and a wish to stick to what feels safe, can be a reason behind the decision to go on as before – "Well, it's safe, I mean, it's my home ground" (P2). If it works, there is little need for alterations:

> If you like what you do and it works it's probably, like, the habit makes it 'no, but this works for me, so …'. And of course, the older generation is maybe more like that and the new generation is more questioning, like, 'shouldn't we do it in another way?' (P8)

Other personal factors that are mentioned in connection with motivation in decision making are personal well-being, and what can be described as personal sustainability – "… you have to live, too" (P2). Having extensive **knowledge** about one's current crops, and the challenge of acquiring knowledge about a new crop, are also mentioned.

> Is there something I can learn, how do I understand their language, because I have … it's always … it's challenging to learn a new crop or plant or vegetable. (P2)

To summarize, economic factors are at the centre of decisions regarding crop choice. All participants are farm entrepreneurs, and running a business with figures constantly in the red is not sustainable. However, the foundation for what can be achieved in the farm enterprise lies in the physical characteristics of the farm – its size, location, and the nature of its soil.

While the two factors mentioned above – the aim of economic sustainability, and the restrictions and/or opportunities rooted in physical properties – appear fixed and inescapable, in between are other factors that may influence decisions in a less definitive manner. The amount of work that the farmer is willing or able to devote to the management of the farm can be a factor, where crops or crop types may be excluded from the crop sequence based on their labour requirements. Motivation can also stem from what the farmer finds interesting and enjoyable.

This summary indicates that 'Achieving economic sustainability' is the overarching theme in farm decision making, with a base in 'Feasibility – practical concerns in relation to pre-existing conditions', and with some influence from 'Personal motivation and abilities'. 'The farm in a bigger context', however, doesn't appear to play any significant role.

3.3.3. Preconditions for change

What could motivate you to change your crop rotation, what would it take? The responses to this question are diverse.

When asked about their plans for the future, four participants replied that they don't foresee any major changes in their crop rotations. P2 is considering expanding her crop rotation to include horticultural crops to improve profitability and also for reasons based on personal interest. P6 is facing an increasingly worrying situation with weeds and is therefore increasing the share of arable crops (i.e. ley).

Achieving economic sustainability

P3, when asked whether he would consider trying horticultural crops, stresses the economic risk and investments involved in going from an arable crop rotation to including vegetables:

> No, I won't. You don't take that up today, how do you mean? Then you have an ordinary farm, a bit of grains, quite a lot of grains, a bit of rapeseed and maybe a few sugar beets too, but it doesn't require anything in terms of staff, it doesn't require any investment in machinery, and it doesn't require irrigation and things like that. So you simply don't take that up. To overcome that, overcome that obstacle, that start, it's pretty massive today, or terribly massive. (P3)

Economic concerns are, however, also mentioned as potential motivating factors, e.g. if the crops currently grown on the farm were no longer profitable, a change would be necessary. Also, new opportunities could be an incentive to make changes to the crop rotation, as for P6, who is considering energy crops as energy prices soar, and oats to meet a rising demand for gluten free products.

Feasibility – practical concerns in relation to pre-existing conditions

Going from an arable to an integrated rotation means an increased **workload**, as horticultural crops require more manual work – work that you have to do yourself or that you hire someone to do. When asked if he would like to grow vegetables, P1 quotes his age as an obstacle to taking up a new type of crop rotation:

> I mean, you could grow a little, but not on a large area, because I'm too old for that. No, but I mean, then you need help because you can't do that when you are over 60. (P1)

Conversely, but related, going from an integrated crop rotation to exclusively arable crops could be prompted by a wish to reduce the workload with increasing age: "If, with time, I can't cope with the vegetables, then … maybe we'll just have grains." (P4)

While **characteristics of the farm** can be an obstacle to change, such as the soil not being suitable for certain crops ("I'm sure there are crops that would be exciting

to try, but brick clay is rarely optimal for those crops" (P7)), new varieties might make it possible to introduce new crop categories:

> Maybe there are new, modern arable crops that might work better on light soils, so I'm sure there are things you can, I mean something else, but you don't think that light soils and grains is the best combination and then maybe you're not too keen on picking that up, unless you have to. (P8)

The farm in a bigger context

A **network** can provide the knowledge and cooperation needed when you start something new. A lack of contacts for selling grains is mentioned by P8 as a problem associated with introducing arable crops in their rotation. P2 mentions cooperation with students or researchers as an opportunity to tap into their experiences:

> Well, I'm thinking, maybe I should check with you students because you get around and see things, 'but NN, why don't you try this, it has pretty low production costs and it is quick to start, and …' … as a student you always keep better track of what's going on. (P2)

Having someone to collaborate with is helpful when venturing into a new field. For instance, working closely together with a farmer who has livestock who could buy ley from you, or that you can exchange land with, appears as an alternative for P8, who at present doesn't see arable crops as a realistic option. Getting a group of farmers together to investigate opportunities and seek advisory service to set up production and logistics for a few crops seems like the way forward for P2, who feels that taking up a new crop can be too much of a challenge for a single farmer:

> I looked a bit at growing flowers, and I was in touch with the Farmers Association about it, but it was going to be, it was going to be so terribly small-scale, that I would, partly from the farm shop, that I would sit by myself and tie bows around bouquets and sell them at the roadside which I gave up on pretty much right away. I did an estimation and felt that darn it, there'll be nothing left to show for it. (P2)

Producing for the food processing industry is an option that could come with promises of support in the form of know-how and logistics, as well as a secure sales channel:

> If Findus[5] or Felix would call and say, hey, we need cucumbers, we know that they grew cucumbers on your farm 15 years ago … Well, first of all, how much are you paying, and how can you support me because I haven't grown cucumbers in 15 years, and do we have someone who can harvest them, and how do we run the logistics? Can you sort of support me with advisory service on how to set it up? We have a cropping plan here. And that is what Foodhills are doing now. (P2)

[5] Findus, Felix and Foodhills are large food processing corporations.

On a **societal** level, only P8 spontaneously mentioned regulations imposed by the authorities as a reason to changing their crop rotation: "I think maybe it would have to be something that someone from the outside comes and tells you, actually, that you, that it has to be done."

P8 expresses a belief that the future will bring more regulations that will require farmers – of both horticultural and arable crops – to adjust both crop choice and management practices in order to reduce the negative environmental impact of farming. In this context, P8 agrees that such regulations being paired with subsidies to compensate for monetary losses would ease the burden and facilitate compliance.

On the issue of the farm in relation to **environmental issues**, while declaring a general wish to be environmentally friendly, none of the participants state that new information on the environmental impact of farming would prompt them to change their crop rotation. P5 questions the fairness in asking farmers to shoulder the full responsibility for the consequences of food production and argues: "I think that is a topic for world opinion to discuss. If I should take that responsibility or if it is an opinion all over the world." (P5)

Personal motivation and abilities

There is a high threshold to cross in order to switch from a specialized to an integrated crop rotation. P2 and P8 talk about how introducing a new category of crops requires new **knowledge**, e.g. on how they affect other crops in the rotation and on how to market them, and before that knowledge is in place, including the new crop will come with a greater risk.

Regarding **motivation and emotion**, P2 also points out the fact that it is a big step to introduce a new type of crops, and that her own sustainability is affected: "And then my perseverance, it affects my environment, my sustainability, my own … that I can cope. The step, to take this, do I have the stamina for this."

The force of habit appears as an obstacle to change – "It's always easier to continue in the same tracks" (P8) – and a feeling of insecurity might stop you from attempting something that you have no experience with:

> I mean, if you don't have a tradition to do something, it is probably hard to jump on a train when you don't know where it's going. But if you have done something before, maybe you have a hunch about the next station and then maybe you find the courage to do it. But that is a hypothetical question. (P5)

References were made to finding inspiration from others as something that might actuate change. P2 mentions input from students and researchers, while P8 expressed that seeing a neighbour try something new can ignite a thought process:

> Sometimes it's good to get input from the outside to make you think. So, of course, when you see others doing things or attempting things, you get an eye-opener, well, maybe we should try that, so it is definitely inspiring, sure. (P8)

In summary, the main disincentives to introducing horticultural crops in a hitherto arable crop rotation are the large investments needed and the anticipated increase in workload. Conversely, going from a horticultural to an integrated crop sequence will result in lower earnings and will also entail investments in machinery. In general, obstacles to changing one's crop rotation can lie in physical factors e.g. soil type, or personal factors like force of habit or the fact that introducing new crops necessarily involves acquiring a substantial amount of new knowledge.

Economic concerns can motivate a change in two ways: if the crops currently grown on the farm should no longer be economically viable, or if new opportunities in the form of demand for certain products should arise. Motivation to change the composition of crops on the farm can also stem from inspiration by successful attempts made by other farmers, or a wish to reduce one's workload. Ultimately, as the barriers to change may be too high, regulations imposed by the authorities might be necessary to warrant a change.

Factors that can facilitate a change in crop composition centre around network – in terms of contacts needed to market new products, partners for collaboration and as a source of knowledge. Partnership with and support from a large buyer can help in an introductory phase.

The farm in relation to environmental issues does not appear to have potential to motivate a change in crop composition.

4. Discussion

4.1. Current situation and farmers' attitudes

4.1.1. Prevalence of integration

The results show that 6.9 percent of Scanian farmers produce both horticultural and arable crops – 10 percent if table potatoes are categorized as horticultural. Very few grow exclusively horticultural crops. Farmers growing both crop types are especially numerous in the plain areas with specialized crop production and in the middle area (farming areas 1 and 3), and to some extent the plains with mixed farming (area 2). Unsurprisingly, they are rare in the mixed farming area and the forested area (areas 4 and 5), where ley dominates on arable land (Johansson et al., 2014). Integration is more common among larger (>100 ha) farms, which in turn are relatively few in area 4 and 5 (Swedish Board of Agriculture, 2021b).

4.1.2. Perceptions of integrated crop sequences

The results of the survey suggest that farmers believe that integrating horticultural and arable crops has a positive effect on profitability, compared to the effect on yield stability, spread of toxic substances, workload, and eutrophication. The effect on biodiversity and spreading of risk also end up on the top half of the ranking, but this result is not statistically significant. As a majority of respondents are specialized in arable crops, the result can be presumed to primarily reflect perceptions of integrated crop rotations compared to arable rotations.

The results of the interviews confirm the view of integrated crop rotations as potentially more profitable, and that this comes at the price of a heavier workload when compared to crop rotations with only arable crops. The results also suggest that integrated rotations are thought to be prone to a higher level of risk. Perhaps the responses reflect dual perspectives: a higher crop diversity is a way to avoid putting all your eggs in one basket; however, vegetables are associated with higher risk and lower yield stability than arable crops.

The participants offer few opinions regarding the environmental impact of integrated rotations. Concerning nutrient leaching, opposing opinions were

declared – on the one hand, that horticultural crops contribute more to eutrophication through leaching due to more tillage, shorter cultures, and higher fertilizer applications; on the other hand, that the more controlled growth of horticultural crops, and fertilizer application optimized based on plant need and nutrient availability, makes for less nutrient leaching than in arable crops. The first viewpoint is more consistent with research on the subject, which concludes that vegetable production is associated with increased runoff and leaching compared to arable cropping systems (e.g. Li et al., 2019b).

Soil health is believed by the participants to be negatively affected by vegetable crops, due to more open soil, irrigation, and tillage, while grains and ley improve soil health by increasing soil organic matter and improving structure. Shifting from cereal to vegetable production has been shown by Lu et al. (2021) to lead to a significant decrease in soil organic carbon and N content and an increase in soil acidification. Integrating with arable crops is seen by some participants as a way to mitigate the unavoidable negative consequences of growing vegetables – again, consistent with research findings. For instance, incorporation of crop residues from cereals or ley will increase organic matter and improve nutrient cycling and availability, thereby allowing a reduction of external fertilizer input (Lu et al., 2021; Conyers & Moody, 2009; Råberg et al., 2019; 2018), and inclusion of legumes will similarly reduce the need for fertilizer input due to their biological nitrogen fixating properties (Sánchez-Navarro et al., 2019).

Regarding perceptions of effect on plant protection, in the survey this factor is in the middle of the ranking, not significantly separate from any other factor. The responses in the interviews are also divergent, with several participants maintaining that it is not a straightforward question, that the nature of plant protection issues may differ between horticultural/arable/integrated rotations, but that the level of problems may not be very different – nor the level of importance for successful farm management. The exception is the issue of weeds, where horticultural crops are described as more problematic. Not least because of a dwindling number of options when it comes to chemical weed management – an opinion, raised by one participant, that is confirmed by evidence of an increasing number of herbicides being taking off the list of approved substances (Viketoft et al., 2019; Carlsson Ross et al., 2015). Also, horticulture is a small market for chemical companies, and registering substances is expensive and time-consuming (VINNOVA, Energimyndigheten & Formas, 2016; Carlsson Ross et al., 2015). The same can be said of Sweden – it is a small country and therefore a small market, which is why many chemical companies choose not to register their products here.

A possible interpretation of the fact that respondents in the AH category (in the survey) have a more positive view of the effect of integrated crop rotations on soil health and plant protection is that they may compare integration to a pure horticultural rotation, while the A category compares it to arable production. One

can also speculate that for the AH respondents, an already existing belief in the positive effects of integration may have motivated them to adopt such a rotation. If such motivation concerns the farmer's wish to be environmentally friendly – an ethical value – it can be seen as intrinsic motivation, where the goal is the action itself (Lens & Vansteenkiste, 2020; Greiner et al., 2007). If, on the other hand, the positive effects of integration are seen as instruments to reach a goal such as improved yield, the motivation is said to be extrinsic.

4.1.3. Incentives and disincentives in choice of crop rotation

Respondents in the survey rate physical characteristics of the farm and economic factors highest among factors influencing decision making, in general terms. Social factors were rated lowest. When the question was more specifically about the motivation behind their choice of crop rotation, physical characteristics were again at the top, together with personal interest, while economic factors were not a significantly stronger motivator than any other. Environmental considerations, force of habit and access to advisory service appear to have the least influence.

In the interviews, economic factors are paramount when respondents state their main motivators, but the characteristics of the farm determine what is attainable – mirroring the results of the survey. Workload and time constraints are also factors in decision making. The obvious focus on economic factors is in agreement with previous writing on the subject, e.g. Pannell et al. (2006) describing wealth both as an end in itself and as a tool to achieve other goals. The fact that several participants express a wish to care for the environment but don't allow environmental concerns to motivate their crop choices is in keeping with Dias et al. (2014), who maintain that farmers are not likely to adopt new practices that reduce the environmental footprint of the farm without expecting some financial return.

Farmar-Bowers & Lane (2009), Pannell et al., (2006) and Öhlmér et al., (1998) have described how personal enjoyment and values can provide motivation for farmers' decision making, which is also apparent in the survey as well as the interviews where enjoyment and interest, personal well-being, and force of habit feature among the responses regarding crop rotation decisions. The notion of the farmer as a steward, caring for the land (Verhoog et al., 2003) can be said to be represented in the participants declarations of consideration for the environment, but especially in the statement of P5: "I believe that the land is just a loan."

Neither the survey nor the interviews gave reason to believe that social goals such as approval or acceptance by others influence the participants – things that are mentioned by Pannell et al. (2006) as potential motivators.

In terms of what is needed to take the step to change one's crop rotation, better market opportunities and more knowledge are required. Economic motives are indicated – both positive motivators such as new opportunities, and negative motivators such as a reduced profitability of current crops. Obstacles to change are

tangible constraints such as soil type and high investment requirements, and a vaguer notion of there being a high threshold to overcome. Network and partnerships can make change easier – consistent with Öhlmér et al. (1998), who point out that the network is a source of information and/or confirmation for farmers in the process of deciding to implement an innovation. Thus, both what Farmar-Bowers & Lane (2009) term personal components of the opportunities available to farmers (e.g. knowledge, capital, energy, enthusiasm, and network) and one major external component (i.e. markets) are involved.

4.2. Integration of horticultural crops in arable rotations

The results indicate that some farmers are open to change while others are very reluctant and not likely to be easily persuaded. If the aim is to increase the production of vegetables, arable farmers that are sufficiently positive to exploring integration, and not prevented by physical constraints e.g. soil type or climate, need to be motivated to take the step to include horticultural cultures in their crop sequences. At present, a large majority of horticultural producers also include arable crops, which suggests that this is a viable option.

Although specialized horticultural producers are rare, there is also reason to consider motivating them to include for example ley and/or grains to reduce their environmental footprint.

According to Farmar-Bowers & Lane (2009), opportunities are evaluated based on *suitability*, or the degree to which they help the farmer to work towards their motivations, and *availability*, i.e. the degree to which they involve personal and external components that the farmer already has or can easily access. Facilitating access to components that motivate farmers to change their crop composition can therefore be a way forward. Such components include market opportunities, access to capital, knowledge, and networks.

While EU regulations forbid discrimination and demand that suppliers in all member countries can take part in public procurement processes (Directive 2014/24/EU of the European parliament and of the Council), there is a growing interest among local governments to support local food production (Granvik, 2012; Lyckhage, 2015). Food policies adopted by local governing bodies determine quality requirements and objectives – for instance, using public procurement as a tool for supporting regional development – and can therefore mandate procurement officers to elevate demands on suppliers in order to fulfil the aims of the policies.

Making it easier for small producers to bid for tenders in public procurement processes is a way to improve market access for farmers. Local authorities are not allowed to demand that the products they buy are locally produced – however, they may take measures to promote local businesses, for instance by providing advisory service to strengthen farm enterprises or by providing training in public

procurement processes, aimed at helping small businesses participate in tenders for public contracts (The National Agency for Public Procurement, n.d.a). Another strategy is to avoid excessively large contracts, or to make it possible to bid on parts of contracts, since small producers may not be able to commit to delivering large volumes. Dynamic procurement systems are a digital mechanism for procurement of goods that are bought regularly, where producers pre-qualify and then make bids when they can, without having to commit to respond to every particular invitation to tender (The National Agency for Public Procurement, n.d.b). Other options include awarding contracts to local wholesalers who buy from small local producers (rather than awarding contracts directly to producers), and local governments starting their own co-distribution centrals to facilitate delivery of goods for small and/or local business, thereby enabling them to take part in bids (Lyckhage, 2015).

As mentioned, there is evidence of increased consumer demand for locally produced food (Fernqvist & Göransson, 2017). A preference from wholesalers for large volumes and demands on timely delivery is an obstacle mentioned by participants. Direct sale to consumers is a way to bypass wholesalers and provide a better price for the farmer. Two mechanisms for bringing producers and consumers together are CSA and 'REKO-rings'.

Community supported agriculture (CSA) has become increasingly frequent in Sweden in the last ten years (Andelsjordbruk Sverige, n.d.). It involves a direct partnership between producer and consumer, long-term contracts and sharing both risks and rewards. Typically, consumers become members and pay a seasonal fee and in return receive weekly shares of produce during the growing season (Lang, 2010). Farmers involved in CSA cite security and economic benefits as incentives, but also reduced waste, the chance to try something new and to be able to start incrementally which reduces the need for initial investments (The County Administrative Board of Västra Götaland, 2021). Obstacles to achieving profitability are perceived to be the balance between increased profit and workload. There is also a lot of work involved in recruiting a sufficient number of partners/consumers. A challenge is to have enough variety to be able to stagger harvest and delivery, to have something to offer throughout the season (Lang, 2010).

Another channel for direct sales to consumers are the 'REKO-rings', a Finnish concept, which has been rapidly spreading since first appearing in Sweden in 2016 (Rural Economy and Agricultural Societies, n.d.a). Producers and consumers form groups that communicate via social media, where consumers pre-order products which are then delivered to and collected at a pick-up point. While the groups are established by consumers and producers, The Rural Economy and Agricultural Societies ['Hushållningssällskapet'] has facilitated the establishment of REKO-rings throughout the country by providing information and support on behalf of The Swedish Board of Agriculture. As with CSA, selling via REKO-rings can be time

consuming, compared to just selling to one wholesaler, as it entails communicating directly with each individual buyer.

Both CSA and REKO-rings principally attract farmers operating on a moderate scale – for instance, in a study of CSA in the Swedish region of Västra Götaland the mean acreage of participating vegetable producers was 1.31 ha (The County Administrative Board of Västra Götaland, 2021). As the results show that combining arable and horticultural crops is relatively rare among Scanian farms of less than 20 ha, there should be scope for increasing integration in that category – a group of farmers that may benefit from improved direct sales mechanisms. As mentioned, smaller farms also stand to benefit most from the economies of scope associated with increased crop diversity (Chavas, 2008).

At the other end of the spectrum, large-scale buyers in the vegetable processing industry can serve as partners for farmers, offering secure sales and low risk. The importance of a strong processing industry is already recognized; for instance, when Findus closed its factory in Bjuv in northwestern Scania, authorities on national, regional, and local level formed a collaboration with private stakeholders to develop a reference and development centre for circular food production (Region Skåne, Bjuvs kommun, Tillväxtverket & Foodhills, 2018; Livsmedelsakademin, n.d.).

Capital is necessary when starting or developing a business – for example when a farmer looks to diversify by including new types of crops, which may entail investing in equipment or infrastructure. Ensuring access to favourable financing options can be a way to facilitate such attempts. Bank loans are the most common financing option in the agricultural sector (Näslund & Falk, 2014), but banks demand collateral and the payments may be burdensome in the beginning. Other options include public financing and venture capital.

The Rural Development Program (Landsbygdsprogrammet), partly EU-funded, aims to develop agriculture and rural areas, and is a national component of EU's strategy for sustainable development (Swedish Board of Agriculture, 2022d). The program activities are designed to contribute to meeting prioritized goals on environment and climate, competitiveness in agrarian enterprises and job creation in rural areas. In addition to funding for projects and collaborations, financing for starting, purchasing, or developing businesses in agriculture and horticulture is provided. The supports granted for investments and starting a business are meant as complements to other sources of finance as they only cover part of the capital requirements (Näslund & Falk, 2014). The program has been criticized for being too complex and detailed and therefore difficult to administer, resulting in high administrative costs, long processing times and delayed payment of granted support (Swedish National Audit Office, 2018).

Almi is a publicly owned enterprise (owned by national and regional authorities) providing credits and venture capital for starting or expanding a business, for example when entering a new market or investing in production equipment (Almi,

n.d.). To compensate for the higher risk and to avoid competing with private financiers, Almi charges a higher interest than banks. Almi mainly provides loans that complement other sources of finance e.g., bank loans. They also provide "green loans" for investments that can contribute to EU environmental objectives, and microloans for starting small businesses. Commercial websites (e.g., Krea, 2020; Firmalån, n.d.) list the main drawbacks of Almi as the high interest rates, long and complex application processes, and the fact that additional capital must be sought elsewhere.

If increasing the share of local produce in public consumption, promoting direct sales mechanisms, and improving access to financing are immediate ways to address the need for better access to markets and capital, funding research and promoting advisory service, networking and collaborations are more long-term measures for addressing the less tangible hurdles experienced and expressed by the participants in the interviews. For instance, funding research, promoting advisory services, and simplifying regulations are suggested courses of action for Swedish authorities to ensure access to appropriate and adequate plant protection methods that are necessary for farmers to venture into horticultural production (VINNOVA, Energimyndigheten & Formas, 2016). Collaboration among farmers, and between farmers and advisory service providers or researchers, could provide the supportive environment needed to encourage farmers to attempt adding new crops to their rotations. In this context, existing organizations e.g. the Federation of Swedish Farmers (LRF) and the Rural Economy and Agricultural Societies (Hushållningssällskapet) would be suitable partners, thanks to their experience and large number of members (134 000 and 25 000, respectively) (Federation of Swedish Farmers, n.d.; Rural Economy and Agricultural Societies, n.d.b).

As risk aversion is a strong motivator in farm decision making, risk reduction can be seen as an incentive for farmers to increase the complexity of crop sequences (Di Falco & Chavas, 2006). But as the results show that vegetable production is viewed as laden with high risk and low yield stability, other mechanisms to reduce risk may be indicated. Publicly subsidized crop insurances exist in several countries but were ended in Sweden in 1994 (Ministry of Agriculture, 1994). Commercially available insurances have limited coverage, most commonly compensating for hail damage, and do not include insurance policies for crop losses due to drought or flooding (Swedish Board of Agriculture, 2019b). The reason for this inadequacy is believed to be that the premiums for such insurances would be too high to be attractive to farmers. EU's common agricultural policy (CAP) allows member states to subsidize crop insurances, which could then be competitively priced (Swedish Board of Agriculture, 2019b; Ministry of Enterprise and Innovation, 2018). Sweden has thus far refrained from taking advantage of this possibility.

4.3. Critical reflections on method

The questions of validity and reliability are treated somewhat differently in quantitative and qualitative research, and different authors define the concepts differently (Hammersley, 1987). Perceptions of validity can be summarized as dealing with the question of whether the study measures what it sets out to measure, or if the results accurately represent the presence and magnitude of properties in the study objects (Heale & Twycross, 2015; Hammersley, 1987; Merriam, 1995).

Reliability in quantitative research has to do with the consistency of a measure (Heale & Twycross, 2015; Hammersley, 1987). In qualitative research, there cannot be the same expectations that a replication of a study will yield the exact same result, and 'dependability' is sometimes used instead of 'reliability' to describe the desired outcome – an internal reliability rather than replicability (Merriam, 1995; Graneheim & Lundman, 2004). Dependability can be strengthened and demonstrated by triangulation (using more than one method, source, or investigator), peer examination and an 'audit trail', i.e. a detailed description of data collection, analysis, and decisions.

Lastly, generalizability is a desired feature of quantitative research that cannot be viewed in the same way in qualitative research where the goal is in-depth understanding rather than extrapolating from a sample to a population (Merriam, 1995). It has been suggested that generalizations based on qualitative studies should be viewed as working hypotheses rather than conclusions, or that it is up to the consumer of the research to judge to which extent it can be applied to other settings. This is facilitated by giving a detailed account of context, process, and findings (Graneheim & Lundman, 2004) – essentially an audit trail. It has been the aim in this study to provide a clear account of the research process to help the reader assess both the dependability and the transferability of the results.

4.3.1. Quantitative data on farm enterprises

In 2020 there were 7583 farm enterprises in Scania engaging in production on arable land, according to the Swedish Board of Agriculture (Swedish Board of Agriculture, 2021b). The data used in this study covers 7249 farm enterprises. Thus, the data covers a large majority of Scanian farmers, indicating that the results accurately reflect the actual properties of the population. A remaining question mark regards 'farming area 0' where the address of the company is outside Scania, giving no indication of where the farming takes place. However, they are relatively few: only 95 (i.e. 1.3%). It is also possible that some of the addresses within Scania represent farm enterprises where the actual farming is undertaken in a different location, thus giving an incorrect picture of the geographical distribution of farms. The presence of such cases is not deemed high enough to seriously distort the results.

Whether potatoes should be considered an arable or a horticultural crop is not straightforward. There are cultural differences: in Sweden, potatoes are a bulk staple, while in some countries they may be viewed as a vegetable. While potato farming shares some characteristics with arable farming, e.g. an often large-scale, extensive production system, it also has features in common with horticultural crops since it doesn't contribute much organic matter to the soil and leaves more open soil than e.g. grains. One notion is that the line is drawn between fresh (or new) potatoes (horticultural) and regular table potatoes (arable). The crop codes used by the board of agriculture does not distinguish between fresh and regular potatoes – only between table potatoes and potatoes intended for starch production (Swedish Board of Agriculture, 2022c).

Because of preconceptions based in previous experiences of the author, potatoes were coded as arable in the questionnaire. This also seems to tally with the classification used by the Swedish Board of Agriculture: their statistics database reports 533 farm enterprises engaged in horticultural field production (Swedish Board of Agriculture, 2021b), which is very close to the number identified in the data analysed in this study, where 520 farmers growing horticultural crops were found when potatoes were categorized as an arable crop. However, during the interviews it became obvious that several of the participants view potatoes, especially fresh potatoes, as a horticultural crop. This is also apparent in different written sources (e.g. Aitken, 2012). The decision to perform the analysis in two sets, using both categorizations of potatoes, was an after-the-fact attempt to reflect the presence of the two perspectives.

The data shows how common it is that farmers in Scania engage in both horticultural and arable production. However, as the data represents the situation in a single year it is not possible to ascertain whether the two types of crops are grown in succession in the same field – which is how 'integrated crop sequence' is construed in this thesis – or spatially separated within the farm. This fact creates an ambiguity in the results, thus weakening the validity of this part of the study.

4.3.2. Survey

Can the results of the survey be expected to reflect the true attitudes of the respondents? Combining, as it does, quantitative and qualitative methods, it is an example of triangulation which is considered a tool for strengthening validity (Merriam, 1995). A further element of triangulation is added by the interviews. The main problem with the survey is the low response rate, which naturally weakens any claims to generalizability.

The length of a questionnaire has an impact on the completion rate, in the sense that drop-out rates tend to be positively correlated with questionnaire length (Manfreda & Vehovar, 2002). For this reason, the aim in designing the questionnaire was to keep the number of questions to a minimum. A high drop-out

rate is not the cause of the low response rate, as only three out of 24 respondents left the questionnaire unfinished. Methods suggested to increase response rates include communicating the purpose and significance of the survey, emphasizing anonymity and confidentiality, a professional layout, multiple attempts to reach the target group (including advance notice and reminders), and incentives, possibly for tangible rewards such as money or tokens (Dörnyei & Taguchi, 2010). While attempts were made to meet the first three suggestions, constraints in time and resources precluded using multiple communications and incentives to boost responses to the survey.

When the survey design influences answers and leads the respondents in a specific direction, the result is response bias (De Veaux et al., 2015). Respondents may be influenced by the phrasing of questions; they may want to please the researcher, or they may not want to divulge personal information. In the context of this study, it is possible that the respondents' interpretation of the questions may have led them to believe that the researcher puts a higher value on integrated crop sequences, which may antagonize participants who specialize in either arable or horticultural crops. This is suggested by one of the free text answers, where a respondent describes a diversified crop sequence without horticultural crops and questions whether singling out the contribution of horticultural crops is fruitful.

The ideal sampling method is the simple random sample, made by a randomized selection of a number of individuals in the population (De Veaux et al., 2015). The respondents of the survey undertaken for this study represent a voluntary response sample, where a very large number of potential respondents were invited to take part. In such cases, people with strong (especially negative) opinions or emotions are more likely to respond. This leads to a skewed sample, burdened with voluntary response bias. The related term nonresponse bias also relates to the fact that those who don't reply may be different from those who do. A small, randomized sample, with the chance to ensure a high response rate, is considered preferable to a large group of potential respondents with a low response rate.

Hypothesis testing is about finding unusual events (Abdi, 2007). The larger the number of tests, the greater the chance to find something unusual that is interpreted as a significant result. When the null hypothesis is thus rejected even though it is, in fact, true, the result is a Type I error. Lowering the alpha level is a way to avoid Type I errors, but this method can increase the risk of Type II errors, i.e. real results are missed as the null hypothesis is not rejected when it should have been.

In the light of this dilemma, it appears that there is a flaw in the survey design inasmuch as there are too many factors in the matrix questions, leading to a large number of comparisons being made in the analysis. Dividing the factors between several questions, or combining several factors into fewer, would have increased the chance of a stronger result. Dunn's post-hoc test is considered conservative, as the per-comparison alpha is adjusted to very low levels if the number of

comparisons is large (e.g. with ten comparisons at an alpha level of 0.05, Dunn's formula with a Bonferroni correction results in a per-comparison alpha level of 0.005) (Glen, 2017). It is not considered a powerful test (a higher statistical power means a lower risk of Type II errors). Thus, the results of the survey may be overly cautious in terms of how many statistically significant differences were detected.

4.3.3. Interviews

The qualitative research interview is not associated with as many standards and methodological conventions as for example surveys (Kvale & Brinkman, 2014). Its success depends largely on the interviewer's skill, interpersonal sensitivity, and prior knowledge of the research topic. It is sometimes criticized for being subjective, unreliable, and biased, with results that lend themselves poorly to generalizations.

This said, the qualitative interview can be a tool to explore the lifeworld of the participants and to give a nuanced image of their experiences and attitudes (Kvale & Brinkman, 2014). It provides space for ambiguity and for the unexpected. It lends itself well to this study, as one of the objectives is to explore the perceptions, attitudes and views of farmers concerning integrated crop rotations.

Purposive sampling is sometimes viewed as unscientific and resulting in data unfit for statistical analysis, but in the context of semi-structured interviews it will serve to optimize the collection of appropriate data and valid findings (McIntosh & Morse, 2015). Participants are selected based on their specific experiences or knowledge pertaining to the research question, not to represent the larger population. A variable purposive sample, specifically, consists of participants that represent the full scope of the desired group of informants (McIntosh & Morse, 2015) – thereby adding to the credibility or validity of the results (Graneheim & Lundman, 2004).

An interview may potentially be stressful for the participant; it may be intimidating, or cause distress if the participant's self-image is challenged by the interaction (Kvale & Brinkman, 2014). Apart from the obvious ethical implications, such experiences may influence the results. In this study, care was taken to avoid value-laden wordings that could potentially be hurtful or infer bias on the part of the researcher which could cause the participant to retreat into a defensive position – or, alternatively, to consciously or subconsciously provide answers aimed at pleasing the researcher. Targeted probes, aimed at prompting the participants to cover multiple aspects of the research questions, were used. Targeted probes may also influence responses or induce participants to adjust their responses to please the researcher (Hsieh & Shannon, 2005).

An inductive approach was used in the analysis of the interviews. There are, however, deductive elements in the process as the research objectives influence the data driven inductive interpretation of the material (Thomas, 2003). The

preconceptions of the researcher are involved in formulating the research objectives – thus there is a risk of confirmation bias, i.e. that the researcher is more likely to identify evidence supporting his/her preconceptions (Nickerson, 1998). The detailed description of the analytic process in this study is aimed at increasing the dependability and transferability of the results.

4.4. Conclusions

There are several obstacles to overcome in order to increase vegetable production by means of expanded use of integrated crop rotations. High investment requirements, high risk, and personal reluctance to make the change are hurdles faced by farmers contemplating adding new crop types to their rotations, often overshadowing incentives such as higher profits.

Any stakeholder wishing to promote integrated crop rotations should endeavour to facilitate access to the personal and external components that are needed for farmers to be able to benefit from the opportunities that integration can offer. This includes facilitating marketing and sales, for instance by continued and increased support to direct sales channels such as REKO-rings and CSA, and by increasing public procurement of local produce.

Improved access to capital is another component. Both the Rural development program and Almi have shortcomings that prevent them being truly helpful. More efficient and transparent processing of applications as well as sufficient levels of financing and reasonable interest are needed.

In the light of future increases in weather extremes due to climate change, and currently inadequate risk management mechanisms, subsidized crop insurances should be considered.

To promote networking, initiatives of collaboration should be supported. Farmers could benefit from each other's experience, working together to overcome initial hurdles, and ways to promote such collaborations in partnership with various farmers' organizations could be explored. Advisory service agencies and the research community can also be part of a wider network that provides support and facilitates dissemination of knowledge.

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Appendix 1

Crop codes used by the Swedish Board of Agriculture and the classification used in this thesis

Crop code	*Crop*	*A/H/O*
1	Barley (winter)	A
2	Barley (spring)	A
3	Oats	A
4	Wheat (winter)	A
5	Wheat (spring)	A
6	Mixed pulses or clover for fodder/silage	A
7	Triticale (winter)	A
8	Rye	A
9	Maize	A
10	Buckwheat	A
11	Cereal trials	A
12	Mixed cereals	A
13	Mixed cereals and pulses, more than 50% cereals	A
14	Canary grass	A
15	Millet	A
16	Cereals for fodder/silage	A
20	Rapeseed (winter)	A
21	Rapeseed (spring)	A
22	Turnip rape (winter)	A
23	Turnip rape (spring)	A
24	Sunflower	A
25	Oil crop trials	A
26	'Högerukaraps' (oilseed rape with high erucic acid content)	A
27	White mustard	O
28	Oil radish	O
29	Triticale (spring)	A
30	Peas (not for freezing etc.)	A
31	Peas for freezing and other types of preservation	A
32	Fava bean	A
33	Narrowleaf lupin	A
34	Mixed protein crops (pulses/cereals)	A
35	Brown beans (?)	A
36	Vetch	A
37	Chickpea	A
38	Soyabean (for oil)	A
39	Soyabean (fodder)	A
40	Oil flax	A
41	Common flax	A
42	Hemp	A
43	Other beans	A
45	Table potatoes	A
46	Potato for starch production	A
47	Sugar beets	A
48	Fodder beets	A

49	Ley and cultivated grass on arable land with a ley crop not approved for agri-environmental payments	A
50	Ley and cultivated grass on arable land	A
52	Pasture (non-arable land)	O
53	Meadow (non-arable land)	O
54	Forest grazing	O
55	Mountain pasture not entitled to farm and compensation payments	A
56	Alvar grazing	A
57	Ley on arable land (contract with forage drying)	A
58	Grass seeds for ley (annual)	A
59	Grass seeds for ley (perennial)	A
60	Fallow	O
61	Mountain pasture entitled to farm and compensation payments	O
62	Clover seed	A
63	Energy grass	A
65	Willow	O
66	Adjusted buffer zones	O
67	Poplar	O
68	Hybrid aspen	O
70	Strawberry	H
71	Other berry production	H
72	Fruit production	O
74	Vegetables	H
77	Buffer zone	O
78	Nursery with production of permanent crops	O
79	Aromatic plants and vegetable seeds	H
80	Green fodder	A
81	Green manure	O
82	Wetlands	O
83	Christmas trees	O
85	Horticulture (not vegetables, fruits or berries)	H
86	Crop not eligible for single payment scheme (only certified organic or recycling agriculture)	O
87	Other crop eligible for single payment scheme (only certified organic or recycling agriculture)	O
88	Other land use arable land	O
89	Mosaic pasture	O
90	Land poor in grasses	O
95	Pasture and meadow under restoration	O

Appendix 2

Questionnaire (translated)

Crop rotations in sustainable cropping systems

My name is Stina Mortensen and I am a student at the Horticultural Science master program at the Swedish University of Agricultural Sciences in Alnarp. The topic for my master's thesis is crop rotations that include both arable and horticultural crops (e.g. both grains and vegetables).

This questionnaire is aimed at exploring how farmers perceive such crop rotations. The target group is farmers engaged in field production, regardless of what crops are included in their crop rotation. Greenhouse production and permanent cultures e.g. orchards are not included.

Participation is anonymous and voluntary. You can choose to leave the questionnaire at any point during the process. The data will be handled in accordance with the General Data Protection Regulation (GDPR) and will only be used for academic purposes. No personal information will be shared with a third party.

The questionnaire consists mainly of multiple-choice questions and takes 5–10 minutes to complete.

Thank you in advance for your participation!

If you have any questions or comments, you may contact me at samo0003@stud.slu.se.

Page 1: Background

Which year were you born? _____

What is your gender?

- o F
- o M
- o Other/prefer not to specify

In which municipality is your farm situated? _____

How big is your farm? Number of hectares: _____

Page 2: The farm

Which of the following best describes the soil type at your farm?

- o Clay/fine silt
- o Coarse silt/sand
- o Clay moraine/moraine clay
- o Moraine

- Peat (organic soils)
- Other/don't know

Which of the following best describes the soil organic matter content on your farm?

- Low (ca <3%)
- Medium (ca 3–%)
- High (ca >6%)
- Organic soil (>20%)
- Don't know

Are you certified organic?

- Yes
- No
- Partly

Do you keep livestock?

- Yes
- No

Page 3: Crop rotation

Arable crops are defined here as grains, legumes, sugar beets, potatoes, oil crops, ley. *Horticultural crops* are defined as vegetables, soft fruit, ornamental plants (only crops that can be part of a field crop rotation; perennial cultures e.g. orchards and greenhouse production are not covered by this study).

Which crops are included in your crop rotation? Select all appropriate alternatives.

- Grains
- Legumes
- Sugar beets
- Potatoes
- Oil crops
- Ley
- Vegetables
- Soft fruit
- Ornamental plants

Page 4: Factors behind decisions

How important are the following factors when you decide what to grow on your farm? Rate on a scale from 1 ('No importance') to 5 ('Decisive importance').

	1	*2*	*3*	*4*	*5*
Economic factors					
Environmental concerns					
Practical issues (e.g. workload, machinery)					
Social factors (e.g. expectations and wishes of others)					
The natural characteristics of the farm e.g. soil type, climate					

Page 5: Sources of information

Where do you find information and knowledge pertaining to crop rotations? Select all relevant alternatives.

- o Advisors
- o Newsletters e.g. from farmers' organization
- o Newspapers and magazines
- o Internet
- o Other farmers
- o Family/friends
- o Researchers
- o Other

Page 6: Crop rotations including both arable and horticultural crops

What will, in your opinion, be the effect of including both arable and horticultural crops in the rotation? Mark how you think the following aspects will be influenced. Rate on a scale from 1 ('Very negative') to 5 ('Very positive').

	1	*2*	*3*	*4*	*5*
Profitability					
Workload					
Yield stability					
Spreading of risk					
Plant protection (management of weeds, pests, diseases)					
The farm's effect on climate change					
Soil health					
Biodiversity					
Eutrophication					
Spread of toxic substances					

Do you have anything to add regarding the effects of including both arable and horticultural crops in the rotation? Please add your comments here! _____

Page 7: Your decisions

This section contains questions to farmers who grow both arable and horticultural crops. The questions cover how different factors have affected your decisions.

How have the following factors influenced your decision to include both arable and horticultural crops in your crop rotation? Rate the appropriate level of influence on a scale from 'Very negative' to 'Very positive'. (A negative effect means that the factor has argued *against* the decision to include both arable and horticultural crops, while a positive effect means that the factor has provided arguments *for* the decision).

	1	*2*	*3*	*4*	*5*
Economy/profitability					
Environmental considerations					
Personal interest					
Access to advisory services					
Fits my cropping system/machinery					
Physical characteristics of the farm e.g. soil type, climate					
Habit/always have					
Spreading of risk					
Workload					

Is there any other aspect that has influenced your decision? Please add your comments here! _____

Will you continue practicing the same type of crop rotation?

- o Definitely
- o Yes, probably
- o Don't know
- o Probably not
- o Definitely not

Page 8: Your decisions

This section contains questions to farmers who specialize in arable crops. The questions cover how different factors have affected your decisions.

How have the following factors influenced your decision to specialize in arable crops? Rate the appropriate level of influence on a scale from 'Very negative' to 'Very positive'. (A negative effect means that the factor has argued *against* the decision to specialize in arable crops, while a positive effect means that the factor has provided arguments *for* the decision).

	1	*2*	*3*	*4*	*5*
Economy/profitability					
Environmental considerations					
Personal interest					
Access to advisory services					
Fits my cropping system/machinery					
Physical characteristics of the farm e.g. soil type, climate					
Habit/always have					
Spreading of risk					
Workload					

Is there any other aspect that has influenced your decision? Please add your comments here! _____

Page 9: Future crop rotation

Will you continue practicing the same type of crop rotation?

- o Definitely

- Yes, probably
- Don't know
- Probably not
- Definitely not

What would be needed for you to choose to include horticultural crops in your crop rotation? Select a maximum of three alternatives.

- Better market opportunities
- More knowledge
- Advisory service
- Subsidies
- Regulations
- Inspiration/example from others
- New information on environmental benefits
- Other/don't know

Can you think of anything else that could persuade you to change your crop sequence? Please add your comments here! _____

Page 10: Your decisions

This section contains questions to farmers who specialize in horticultural crops. The questions cover how different factors have affected your decisions.

How have the following factors influenced your decision to specialize in horticultural crops? Rate the appropriate level of influence on a scale from 'Very negative' to 'Very positive'. (A negative effect means that the factor has argued *against* the decision to specialize in horticultural crops, while a positive effect means that the factor has provided arguments *for* the decision).

	1	*2*	*3*	*4*	*5*
Economy/profitability					
Environmental considerations					
Personal interest					
Access to advisory services					
Fits my cropping system/machinery					
Physical characteristics of the farm e.g. soil type, climate					
Habit/always have					
Spreading of risk					
Workload					

Is there any other aspect that has influenced your decision? Please add your comments here! _____

Page 11: Future crop rotation

Will you continue practicing the same type of crop rotation?

- Definitely
- Yes, probably
- Don't know

- Probably not
- Definitely not

What would be needed for you to choose to include arable crops in your crop rotation? Select a maximum of three alternatives.

- Better market opportunities
- More knowledge
- Advisory service
- Subsidies
- Regulations
- Inspiration/example from others
- New information on environmental benefits
- Other/don't know

Can you think of anything else that could persuade you to change your crop sequence? Please add your comments here! _____

Page 12: Other

Do you have any further comments? Please add your remarks here! _____

Thank you very much for taking the time to respond to this questionnaire! If you would like to read the final report, or if you have further comments, please contact me via e-mail on samo0003@stud.slu.se

Appendix 3

Terms of participation (translated)

Participation in interview study

Participation in interview study within the framework of a master's thesis in Horticultural Science at the Swedish University of Agricultural Sciences in Alnarp, autumn term 2021. Student's name: Stina Mortensen

Aims and objectives
The aim of the study is to explore opportunities and obstacles associated with integrating arable and horticultural crops in a crop rotation.

The topic of the thesis is crop rotations including both arable and horticultural crops, e.g. both grains and vegetables. The aim is to examine the advantages and opportunities that are associated with integrating the two types of crops, but also the disadvantages and obstacles.

The interviews aim to explore farmers' reasoning regarding crop rotations and what is most important when they choose crops, and how they perceive crop rotations that include both arable and horticultural crops. The study include both farmers that specialize in one crop type, and farmers that include both types.

Terms of participation

- Participation is voluntary and no compensation is payed. The participant may at any time withdraw his/her consent to participate.
- The student will perform a telephone interview with the participant. Expected duration: 20–30 minutes.
- The interview will be recorded and transcribed verbatim. The participant is entitled, at his/her request, to read the transcript in order to correct any errors.
- The participant is entitled, at his/her request, to read the results and the finished report.
- The participant has the right to remain anonymous, or to consent to his/her name being used in the report.
- The finished report will be published at Epsilon, SLU's archive for students' theses, and will thus be available to the public.

If you want to know more about how SLU handles personal data and about your rights, information is available at www.slu.se/personuppgifter.

Appendix 4

Interview guide
(Translated)
Suggested prompts in italics

- Introduce myself
- Inform about the aim of the study
- Explain the terms of participation
- Briefly describe the structure of the interview

Part 1. Background
1. Which year were you born?
2. What is the size of your farm (how many hectares)?
3. How long have you been farming?
4. How would you describe the soil type at your farm?
5. How would you describe the organic matter content of your soil?
6. Is your production certified organic?
7. Do you have animals?
8. Which crops are included in your crop rotation?

Part 2.
9. Who makes decisions regarding crop rotation on your farm?

10. What is most important when you decide what to grow on your farm?
(Economic/environmental/practical/social factors, physical characteristics of the farm)

11. Where do you find information and knowledge on issues regarding crop rotation?

12. Think about a crop rotation including both arable crops, i.e. grains, sugar beets, oil crops, and horticultural crops, mainly vegetables. What are the advantages and disadvantages?
(Profitability, workload, yield stability, spreading of risk, plant protection, effect on environment)

13. Are such crop rotations new – or something old, commonplace?

For participants with integrated crop rotations:
14a) Have you always included both arable and horticultural crops?

15a) Explain why you choose to grow both arable and horticultural crops [previously mentioned crops]!

(Factors influencing your decision; profitability, environment, interest, access to advisory service, fits my cropping system/machinery, habit)

16a) Can you identify any tangible advantages, positive effects?
(Soil health, weeds/pests/diseases, yield)

17a) What are the disadvantages?

18a) What are your plans for the future? Will you change your crop mix (will you continue with an integrated crop rotation)?

19a) Is there anything that would make you change your mind and choose to no longer include both arable and horticultural crops?
(Market opportunities, yield, new knowledge, advisory service, subsidies, regulations, inspiration/example from other farmers, new information on [environmental] benefits)

20a) Is there anything you would like to add?

(Finish and thank the participant.)

For participants that specialize in arable/horticultural:
14b) You specialize in arable/horticultural production. Have you always had this type of crop rotation, with [previously mentioned crops]?

15b) Explain why you choose this type of crop rotation!
(Factors influencing your decision; profitability, environment, interest, access to advisory service, fits my cropping system/machinery, habit)

16b) Can you identify any tangible advantages, positive effects, of specializing in arable/horticultural/previously mentioned crops?

17b) Are there any disadvantages associated with not including both arable and horticultural crops?

18b) What are your plans for the future? Will you change your crop mix? Would you like to include also arable/horticultural crops?

19b) Is there anything that would make you change your mind and choose to include both arable and horticultural crops?
(Market opportunities, yield, new knowledge, advisory service, subsidies, regulations, inspiration/example from other farmers, new information on [environmental] benefits)

20b) Is there anything you would like to add?

(Finish and thank the participant.)

Appendix 5

Examples of the coding process from meaning unit to category. The meaning units in this example have been translated into English for the sake of demonstration.

Meaning unit	Condensed meaning unit	Code	Subcategory	Category
So I don't know, but I'm thinking, the advantage is that you are pretty flexible that you can grow almost anything, but we are very market oriented, I mean we are very much controlled by what people actually want and can buy.	You are under pressure from the market, what people want and can buy.	Demand	Being able to sell one's products	Achieving economic sustainability
Well, it's to have something to offer, partly to have something to eat myselft because I'm a vegetarian since 45 years, and the whole family is vegetarian, and, well, to have something to sell more directly to consumers because grain is not really a big item in that context.	To have something to sell directly to consumers, and grain is not suitable for that.	Sell directly to consumer	Being able to sell one's products	Achieving economic sustainability
Yes it will, I mean, strawberries are a labour- and, well, what shall I call it, capital-intensive crop, but that also means that you can get a turnover and hopefully a profit on a smaller acreage.	Strawberries can provide a turnover and profit also on a small acreage.	Profitability	Making a profit	Achieving economic sustainability

Appendix 6

Post-hoc analysis results, Dunn's test, SPSS

Significant differences highlighted.

Factors influencing decision making:

Pairwise Comparisons of Factor

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Social-Environmental	26,167	9,080	2,882	,004	,040
Social-Practical	43,214	9,080	4,759	,000	,000
Social-Economic	56,571	9,080	6,230	,000	,000
Social-Physical	64,405	9,080	7,093	,000	,000
Environmental-Practical	-17,048	9,080	-1,877	,060	,605
Environmental-Economic	30,405	9,080	3,349	,001	,008
Environmental-Physical	-38,238	9,080	-4,211	,000	,000
Practical-Economic	13,357	9,080	1,471	,141	1,000
Practical-Physical	21,190	9,080	2,334	,020	,196
Economic-Physical	-7,833	9,080	-,863	,388	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Effects of integrating arable and horticultural crops:

Pairwise Comparisons of Factor

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Yield st-Toxic	2,167	17,568	,123	,902	1,000
Yield st-Workload	6,167	17,568	,351	,726	1,000
Yield st-Eutroph	10,667	17,568	,607	,544	1,000
Yield st-Climate	23,833	17,568	1,357	,175	1,000
Yield st-Soil health	33,667	17,568	1,916	,055	1,000
Yield st-Protection	36,810	17,568	2,095	,036	1,000
Yield st-Risk	54,643	17,568	3,110	,002	,084
Yield st- Biodiversity	55,167	17,568	3,140	,002	,076
Yield st-Profit	72,357	17,568	4,119	,000	,002
Toxic-Workload	-4,000	17,568	-,228	,820	1,000
Toxic-Eutroph	8,500	17,568	,484	,628	1,000
Toxic-Climate	21,667	17,568	1,233	,217	1,000

Toxic-Soil health	31,500	17,568	1,793	,073	1,000
Toxic-Protection	34,643	17,568	1,972	,049	1,000
Toxic-Risk	52,476	17,568	2,987	,003	,127
Toxic- Biodiversity	53,000	17,568	3,017	,003	,115
Toxic-Profit	70,190	17,568	3,995	,000	,003
Workload-Eutroph	4,500	17,568	,256	,798	1,000
Workload-Climate	17,667	17,568	1,006	,315	1,000
Workload-Soil health	27,500	17,568	1,565	,117	1,000
Workload-Protection	30,643	17,568	1,744	,081	1,000
Workload-Risk	48,476	17,568	2,759	,006	,261
Workload-Biodiversity	49,000	17,568	2,789	,005	,238
Workload-Profit	66,190	17,568	3,768	,000	,007
Eutroph-Climate	13,167	17,568	,749	,454	1,000
Eutroph-Soil health	-23,000	17,568	-1,309	,190	1,000
Eutroph-Protection	-26,143	17,568	-1,488	,137	1,000
Eutroph-Risk	-43,976	17,568	-2,503	,012	,554
Eutroph- Biodiversity	44,500	17,568	2,533	,011	,509
Eutroph-Profit	-61,690	17,568	-3,512	,000	,020
Climate-Soil health	-9,833	17,568	-,560	,576	1,000
Climate-Protection	-12,976	17,568	-,739	,460	1,000
Climate-Risk	-30,810	17,568	-1,754	,079	1,000
Climate-Biodiversity	31,333	17,568	1,784	,074	1,000
Climate-Profit	-48,524	17,568	-2,762	,006	,258
Soil health-Protection	3,143	17,568	,179	,858	1,000
Soil health-Risk	20,976	17,568	1,194	,232	1,000
Soil health-Biodiversity	21,500	17,568	1,224	,221	1,000
Soil health-Profit	38,690	17,568	2,202	,028	1,000
Protection-Risk	-17,833	17,568	-1,015	,310	1,000
Protection-Biodiv	18,357	17,568	1,045	,296	1,000
Protection-Profit	35,548	17,568	2,023	,043	1,000
Risk-Biodiversity	,524	17,568	,030	,976	1,000
Risk-Profit	17,714	17,568	1,008	,313	1,000
Biodiversity-Profit	-17,190	17,568	-,979	,328	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

‘Yield st’ = Yield stability
‘Toxic’ = Spread of toxic substances
‘Eutroph’ = Eutrophication
‘Protection’ = Plant protection
‘Risk’ = Spreading of risk
‘Profit’ = Profitability

Factors influencing the choice of integration vs. specialization:

Pairwise Comparisons of Factor

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Advisory-Habit	-1,238	15,778	-,078	,937	1,000
Advisory-Environ	-3,500	15,778	-,222	,824	1,000
Advisory-Workload	-18,476	15,778	-1,171	,242	1,000
Advisory-Risk	-23,167	15,778	-1,468	,142	1,000
Advisory-Economy	-49,333	15,778	-3,127	,002	,064
Advisory-Fits	-52,476	15,778	-3,326	,001	,032
Advisory-Interest	-57,667	15,778	-3,655	,000	,009
Advisory-Physical	-61,143	15,778	-3,875	,000	,004
Habit-Environ	2,262	15,778	,143	,886	1,000
Habit-Workload	-17,238	15,778	-1,093	,275	1,000
Habit-Risk	-21,929	15,778	-1,390	,165	1,000
Habit-Economy	48,095	15,778	3,048	,002	,083
Habit-Fits	51,238	15,778	3,247	,001	,042
Habit-Interest	-56,429	15,778	-3,576	,000	,013
Habit-Physical	-59,905	15,778	-3,797	,000	,005
Environ-Workload	-14,976	15,778	-,949	,343	1,000
Environ-Risk	-19,667	15,778	-1,246	,213	1,000
Environ-Economy	45,833	15,778	2,905	,004	,132
Environ-Fits	-48,976	15,778	-3,104	,002	,069
Environ-Interest	-54,167	15,778	-3,433	,001	,021
Environ-Physical	-57,643	15,778	-3,653	,000	,009
Workload-Risk	4,690	15,778	,297	,766	1,000
Workload-Economy	30,857	15,778	1,956	,050	1,000
Workload-Fits	34,000	15,778	2,155	,031	1,000
Workload-Interest	39,190	15,778	2,484	,013	,468
Workload-Physical	42,667	15,778	2,704	,007	,246
Risk-Economy	26,167	15,778	1,658	,097	1,000
Risk-Fits	29,310	15,778	1,858	,063	1,000
Risk-Interest	34,500	15,778	2,187	,029	1,000
Risk-Physical	37,976	15,778	2,407	,016	,579
Economy-Fits	-3,143	15,778	-,199	,842	1,000
Economy-Interest	-8,333	15,778	-,528	,597	1,000
Economy-Physical	-11,810	15,778	-,748	,454	1,000
Fits-Interest	-5,190	15,778	-,329	,742	1,000
Fits-Physical	-8,667	15,778	-,549	,583	1,000
Interest-Physical	-3,476	15,778	-,220	,826	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

'Advisory' = Access to advisory services
'Environ' = Environmental considerations
'Risk' = Spreading of risk
'Economy' = Economic factors
'Fits' = Fits cropping system/machinery
'Interest' = Personal interest
'Physical' = Physical characteristics of the farm

Appendix 7

Themes, categories and subcategories
Number of participants contributing to each category is presented in parentheses.

Categories	Subcategories content area 1	Subcategories content area 2	Subcategories content area 3	Subcategories content area 4
Theme: Achieving economic sustainability				
Achieving economic sustainability	(8) *Being able to sell one's products *Cost of production *Getting a good price *Making a profit *High risk with horticultural crops *Economic results not most important	(7) *There is a market for horticultural crops *Higher costs associated with horticultural crops *Horticultural crops (and integrated crop rotations) are more profitable *Variety of crops spreads the risk *Higher risk with horticultural crops	(8) *Spread the risk *Being able to sell one's products *Making a profit	(6) *Making a profit *Being able to sell one's products *Investment requirements *New market opportunities motivates change
Theme: Feasibility – practical concerns in relation to pre-existing conditions				
Workload and crop choice	(6) *Time as a limiting factor *Horticultural crops more labour intensive *Distribution of workload across the year *Access to a labour force *The need to buy services	(6) *Heavier workload with horticultural crops *More handwork with horticultural crops *Staff needed with veg	(6) *Amount of handwork a limiting factor *The need to hire workers *Workload as a limiting factor *Management of arable crops can be outsourced *Distribution of workload across the year *Horticultural crops more labour intensive	(3) *Increasing age – can manage less workload *Horticultural crops more labour intensive
Characteristics of the farm	(7) *Size of the farm influences crop choice *Influence of climate *Adapt choices to soil type *Presence of wildlife		(2) *Geographical location matters *Adapt crop choice to soil type *Size of the farm influences crop choice	(2) *Soil type impediment to change *Crops fitting soil
Protecting the crop	(1) *Protecting the crop	(8) *Choice of crop rotation not decisive for level	(2) *Protecting the crop	

		of plant protection problems *More pest management with integration *Weeds a major problem in H but less in A *Lack of pesticide options for horticultural production *Other		
Optimizing the crop rotation	(4) *Crop rotation for plant protection *Crop choice for soil health *Crop rotation for yield *Crop rotation and nutrients	(3) *Crop rotation considerations when including veg *The importance of crop rotation is exaggerated	(2) *Optimizing the crop rotation	
Farm infrastructure	(4) *Irrigation compensates for soil type *Machinery based on crops in the rotation – not the other way around *Existing machinery influences crop choice	(2) *Practical requirements for including vegetables	(2) *Practical arguments against horticultural crops *More flexibility with horticultural crops	
Theme: The farm in a bigger context				
The farm in relation to environmental issues	(7) *Wishing to care for the environment *Choice of crops and management to benefit the environment *Trade-off between environmental concerns and economic reality *Environment not a primary influence	(8) *Effect on environment – it depends! *Negative effect of vegetables *Positive effects of H due to management factors *Impact on climate change not dependent on choice of crop rotation *No opinion		(3) *Wishing to care for the environment
Effects on soil health		(4) *H less favourable for the soil due to less soil cover, more irrigation, more tillage	(2) *Horticultural crops are less favourable for the soil than grain *An integrated crop rotation is more	

		*A is better for the soil due to long cultures, increased SOM *Deep roots and organic material good for the soil	favourable for the soil than a pure horticultural crop rotation	
Network and support	(1) *Network a source of knowledge	(1) *Network needed to sell A	(5) *Access to advisory service is not a decisive factor	(2) *Know-how and support needed to make a change *Network and cooperation can help
Societal factors		(1) *Regulations reduce pest management options	(1) *Trend	(2) *Whose responsibility? *Political decisions needed
Theme: Personal motivation and abilities				
Knowledge and information	(2) *The importance of knowledge	(2) *Knowledge requirements when changing crop rotation		(1) *Knowledge makes it easier to change
Motivation and emotion	(2) *Sources of motivation *Personal sustainability	(1) *Personally demanding to switch from arable to integrated	(8) *Motivation based on interest and enjoyment *Habit and security a reason to continue with the same *Self confidence *Lifestyle	(2) *Personal motivation *The force of habit *Inspiration from others
Other				
		A traditional way of farming		
		Changes in crop choices – in a big perspective		