Sveriges lantbruksuniversitet
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What can be learnt from the 2018 drought and how to adapt Swedish agriculture to a changing climate?

– An exploratory study with farmers from Mälardalen

Serafima Rende

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Serafima Rende

Supervisor: Kristina Marquardt, Swedish University of Agricultural Sciences, Department of Urban and Rural Development.

Examiner: Örjan Bartholdson, Swedish University of Agricultural Sciences, Department of Urban and Rural Development

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Abstract

In 2018, the unusually dry and hot summer caused large losses in agricultural production. Farmers in Mälardalen had to struggle all summer to gather enough animal fodder, working long hours but gaining little in return. Climate change poses a threat to agricultural production because it is sensitive to weather extremes and weather fluctuations makes it harder to adapt to a changing climate. This study aims to explore how drought affected farmers in Mälardalen in 2018. What kind of adaptive strategies did they apply? If and how do farmers prepare and plan for climate change? Are there any opportunities or is climate change only negative? How do farmers think about adaptive management on their farms and what are the challenges to its implementations? The information was collected through semi-structured interviews with five farmers, two farmers' organizations and county board administration from two counties. The findings show that the context plays a crucial role for farmers' adaptability and that every farmer's situation is unique. This also affects their decisions and strategies of adaptive management.

Keywords: Climate change adaptation, adaptability, socio-ecological systems, farming systems, drought, adaptive management.

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Abbreviations and glossary

CAB	County Administrative Board
IPC	International Panel on Climate Change
LRF	The Federation on Swedish Farmers (*Swedish abbreviation)*
SDG	Sustainable Development Goals
SES	Socio-ecological systems
SJV	Swedish Board of Agriculture (*Swedish abbreviation*)
SLV	Swedish National Food Agency (*Swedish abbreviation)*
SMHI	Swedish Meteorological and Hydrological Institute
SOU	Official Reports of Swedish Government (*Swedish abbreviation)*

Lantbrukarnas Riksförbund	The Federation on Swedish Farmers
Livsmedelsverekt	Swedish National Food Agency
Länsstyrelsen	County Administrative Board
Miljö- och energidepartement	Environment and Energy department
Statens jordbruksverk	Swedish Board of Agriculture
Statens Offentliga Utredning	Official Reports of Swedish Government

1 Introduction

Climate change poses numerous threats to agriculture. Potential threats that can be linked to climate change are extreme weather events, raised temperatures, spread of new diseases, impact on animal's health, animal and crop productivity, among others (SOU, 2007:60; Sundström, et al., 2014; Jordbruksverket, 2017:17). Summer 2018 in Sweden provides an example of an extreme weather event that will be central to this study. The discussion of climate change on national level has had a larger focus on climate change mitigation rather than on the adaptive strategies to a changing climate. Only recently has the later discussion been raised, and arguable some of mitigation and adaptation strategies are overlapping.

In their Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) released different scenarios for global mean surface temperature increase for the end of 21st century (2081-2100), ranging from 0,3-1,7°C up to 2,6-4,8°C depending the scenario used (IPCC, 2014a). Swedish Meteorological and Hydrological Institute (SMHI) released their reports (SMHI, 2015a; SMHI, 2015b; SMHI, 2015c; SMHI, 2015d) with assessment of the climate change impacts on county level using IPCC's scenarios RCP4.5 and RCP8.5[1]. SMHI reports how the impacts will depend on the future emission of greenhouse gases. The current annual mean temperature in the study area[2] varies from 4 to 6°C between the counties. The SMHI reports conclude that the temperature increase in Mälardalen (covering four different counties) by the end of the century will range from 3 to 5°C degrees, depending on which scenario is applied. Largest warming will happen during the winter season with up to 6°C degrees of increase. This would in turn prolong the growing season with up to 3 months (in case of RCP8.5 scenario). A warmer atmosphere would further lead to higher evaporation and faster water circulation in the atmosphere which would result more rain. These SMHI reports conclude that the future climate will implicate an 15-35% increase in precipitation and more heavy rains. The increase of precipitation will be most prominent during winter and spring.

[1] Representative Concentration Pathways are scenarios that describe the different trajectories for carbon dioxide emission for the period of 2000-2100. Different scenarios reflect different concentrations of carbon dioxide in the atmosphere, RCP2.6 representing the lowest concentration and RCP8.5 is representing the highest.

[2] Mälardalen, including the county of Uppsala, Stockholm, Södermanland and Västermanland. See chapter 4.1 on study delimitation.

A change of climate which will create a prolonged growing season is expected to be favourable for agricultural production according to Swedish Board of Agriculture (SJV) report (2017:17) and Official Reports of the Swedish Government (SOU, 2007:60) as it would allow an enhanced photosynthesis and biomass production for certain crops. However, there are also recent evidence which indicate that an increase of both CO_2 and temperature may have the opposite effect on photosynthesis and biomass production (Sundström, et al., 2014).

In the summer of 2018, Sweden experienced some record high temperatures and highest amount of hot days[3] in certain parts of Sweden. Temperature is compared to data that has been registered since 1950. The very dry summer also generated many devastating forest fires (SMHI, 2018). SJV expects that summer droughts will become a more frequent problem in the future because of a changing climate. With higher levels of evaporation and fluctuations of precipitation, the soil moisture is expected to decrease. As the increase of precipitation is expected to happen mostly during winter and autumn, more flooding is also predicted to happen during this period. However, the overall assessment from SJV is that the positive effects of climate change will outweigh the negative effects on Swedish agriculture (Jordbruksverket, 2017:17).

The drought during the summer 2018 had a devastating effect on Swedish agriculture to the extent that it was considered to be a national crisis (Regeringskansliet, 2018a). The newspapers reported continuously on the issue. For example, Aftonbladet (Widegren, 2018) reported how lack of water for irrigation resulted in large losses of crops, and how farms with livestock could not produce enough fodder for their animals. The situation worsened with increasing grain prices. Farmers who have had a bad roughage harvest and could not provide enough fodder for their livestock, were forced to send their animals to slaughterhouses. The situation caused an overload at the slaughterhouses and they could not take in more livestock. Because of this, in some parts of Sweden, animals had to be killed and thrown away as carcass instead of going to the slaughterhouses. The Swedish government created a 1,2 billion SEK crisis package to the affected farmers[4] (Regeringskansliet, 2018b). However, many farmers have expressed a disappointment with the subsidies, stating that it would not be covering their losses as each farm would only receive 150 000 SEK as most (Westin, 2018). Despite SJV's positive assessment (Jordbruksverket, 2017:17) of the consequences of climate change in Sweden, what have been experienced in practice after the dry summer in 2018, was that it brought devastation and large economic losses to Swedish farmers.

In 2015, the Ministry of Environment and Energy (Miljö- och energidepartement, 2015) gave SMHI the task to identify actors and their respective responsibilities on how the national work on climate change adaptation should be

[3] When the temperature exceeded 25° degrees (SMHI, 2018).

[4] of which only 460 million SEK would be received in 2018 and the remaining 760 million SEK would be received during 2019 (Regeringskansliet, 2018b)

organised and followed up. The SMHI report resulted in a government submitted proposition on national strategy for climate change adaptation in 2018 (*Regeringens proposition 2017/18:163 - Nationell strategi för klimatanpassning*) which further describes the government's goals and purposes, the roles of different governmental agencies and their strategic action plans to address climate adaptation. The two agencies which are most prominent in their work with climate change adaptation and agriculture are Swedish National Food Agency (SLV) and Swedish Board of Agriculture (SJV).

In the light of these events I will in this study explore what climate change adaptation might mean in practice for farmers. I will do this by using the concept of adaptation as a crucial aspect of socio-ecological systems (SES) (Gunderson & Holling, 2002; Walker, Holling, Carpenter, & Kinzig, 2004; Biggs, Schlüter, & Schoon, 2015) and of fostering enhanced resilience to a system (Holling, 1973). The focus will be on the farmers' perspective of what farm-system adaptation looks like and to understand the farm as a system formed by several interrelated farm components.

1.1 Purpose of the study and research questions

The purpose of this research is to learn about which strategies and practices farmers in Mälardalen, Sweden use to adapt to climate change, both long-term and short-term, and how they perceive climate change. I will use the farming experiences from the drought from the summer 2018 as an example to illustrate what kind of adaptive management is undertaken on farm level. This is expressed in the following research questions:

Research question 1: How were farmers in Mälardalen affected by the drought in 2018 and what adaptive actions (if any) did they undertake?

Research question 2: What threats or opportunities do farmers perceive climate change will cause and how do they plan for it?

Research question 3: What different adaptive strategies are suggested by farmers and what are the challenges for their implementations?

1.2 Thesis outline

After the introduction, the thesis begins with a thematic background of climate change impacts on agriculture and describe more specifically the situation of Swedish context. Chapter three lays out the theoretical framework of this study by presenting concepts such as adaptability and system-thinking. Chapter four provide a methodological description and chapter five presents the findings of this study. This is followed by chapter six and seven that are the discussion and conclusions drawn for the study

2 Background

This chapter will briefly present the discourse around climate change adaptation and agriculture. Then, the context of Swedish agriculture will be presented, showcasing some of its vulnerable aspects and some risks associated with climate change that may have an impact on livestock- and crop production in Sweden.

In recent years, attention has been drawn upon climate impact assessment studies, especially the adaptive and mitigating responses to climate change. Agriculture has been one of the major subjects of attention as it depends on many different biological processes which are tied to climatic conditions. As the climatic changes will affect farming in several ways on the regional scale, it is expected to have a significant impact on both quality and quantity of food production on the global scale (Johnston & Chiotti, 2011). Agriculture is one of the most vulnerable sectors to the risks associated with climate change, but with adaptive strategies the impacts of climate change can be mitigated to some extent and new opportunities may also be realized. The strategies for adaptation may vary geographically according to the local conditions and their economic, political and institutional circumstances. Adaptation as a process, however, remains unclear and according to Smit & Skinner (2002) there is a need to learn which adaptive strategies would be realistically possible, who would be implementing them and what is required to facilitate and develop these strategies. Some of the obstacles for adaptive implementations are not related to climatic conditions, but instead may be connected to the socio-economic contexts e.g. commodity prices, trading agreements, subsidies, access to land and resources, technological and economical boundaries (Smit & Skinner, 2002).

2.1 Threats, risks and vulnerability in Swedish agriculture

Research previously conducted by Camilla Eriksson (2018) aimed to showcase food production in Sweden in case of crisis, utilizing the concept of resilience. Although this study was not specifically focusing on climate change and its threats, the study provides a great insight in the understanding of the vulnerability of Swedish agriculture and some of the future risks posed to it, as well as insights in how to increase its resilience.

The re-structuring of Swedish agriculture throughout the last few decades have led to fewer but larger farms, often specialized in one specific production type (SOU, 2007:60). The re-structuring has also led to a decentralization from national markets and resources, meaning that the farms are dependent on inputs such as fuel, fertilizers, seeds and animal fodder[5] from abroad. The study done by Eriksson (2018) analysed multiple agricultural holdings of different sizes and production types and farmers' dependency of a steady electricity supply (e.g. to run their ventilation systems) and regular deliveries of animal fodder and pickups for culling, as they do not have the additional storage capacity to stock up on fodder or animals for long periods of time.

2.1.1 Climate change impacts on crop production

The quality and quantity of Swedish crop production is dependent on weather conditions throughout the year. Longer growing season as the result of climate change would mean that both sowing and harvest periods would need to change. At the same time, larger weather variations from year to year might give a larger variation in crop output as well. Because of the expected changes to growing season due to climate change, in Sweden it will have a significant impact for spring sowing as it will allow the sowing to be done earlier, while the sowing in autumn may be delayed (Jordbruksverket, 2017:17). A postponed sowing in autumn may have impacts that can affect the quantity and quality of the crop output. While sowing too early in autumn may cause a premature growth that might be harmful for the overwintering of the crop during the winter period (SOU, 2007:60; Jordbruksverket, 2017:17).

As extreme weathers events are expected to become more frequent with a changing climate, there will be more droughts or heavy rains that will cause severe damages to the crop production (Sundström, et al., 2014). The timing of the rain is also important; depending in what plant development stage the rain or drought happens, it will have different effects on the harvest (Jordbruksverket, 2017:17). With a warmer climate, new type of crops which are favourable to warmer climate conditions could be considered. With the expectancy of a warmer and drier climate during summer, especially in the southeast part of Sweden, crops such as corn is expected to become more popular. The conditions for crop cultivations in the study area Mälardalen are expected to change and become similar to the present agro-climate conditions in the southern part of Sweden, Skåne (SOU, 2007:60; Jordbruksverket, 2017:17).

[5] Here we must distinguish between protein fodder and roughage (or energy fodder). Protein fodder is often imported or bought from local producers, while grain, green fodder or ley are often cultivated on own farms and used as animal fodder.

2.1.2 Climate change impacts on livestock production

The economic importance of livestock production and crop production in Sweden is almost equal. Grazing animals are also seen as an important contributor to biodiversity management in the farming landscapes. The long-term work invested in animal health and low diseases pressure in Swedish farming is particular to Swedish farming (SOU, 2007:60). Nevertheless, the increase of temperature may result in heat stress and premature deaths of animals, as well as affect the health of animals in general by decreasing their immunity to disease, fertility, feed intake and overall productivity. Increased temperature may also affect vectored born disease and a northward spreading of certain diseases. Proper cooling and ventilation systems are therefore going to be particularly important in case of raised temperatures (Sundström, et al., 2014; Jordbruksverket, 2017:17). This means that access to power supply will probably continue to be necessary for animal production, as well as transportation to and from the farm. Access to fodder areas and water of good quality is crucial for animal production and especially for milk production. Prolonged periods of droughts may result in lack of both water and fodder, while flooding can have effect on the availability of grazing lands (SOU, 2007:60; Sundström, et al., 2014; Eriksson, 2018). As ecological certified animal production is increasing in Sweden, these types of farms might be especially sensitive to extreme weather events as they are supposed to produce their own animal fodder within the farm and the certification rules restrain the farmer from buying fodder from outside (SOU, 2007:60).

The heat stress begins at different thresholds for different animal species. For example, milking cows can experience mild heat stress already at 21-22° and the stress is significantly increased above 25° where it starts to have a serious impact on milk productivity. The thresholds for pigs where they begin to experience mild heat stress and then decrease of productivity are similar to cows'. For poultry, the heat stress begins at 25° degrees (Jordbruksverket, 2017:17).

3 Theories and concepts

Prior to the fieldwork, theoretical framework and concepts have been chosen to guide the research process and to analyse the collected data. Despite that this study is of an exploratory nature, the theory of socio-ecological systems (SES) and its concept of adaptation have been chosen for the delimitation of the research analysis (for discussion about study limitations, see chapter 7.2). Resilience - specifically of socio-ecological systems - is used as a theoretical entry point and the basis for the discussions of adaptation, adaptive management and adaptive capacity of farm systems. These three concepts will be the main tools for the analysis and discussion of the findings in later chapters. Therefore, this chapter begins with an introduction of resilience of socio-ecological systems. From there, I will go more into the description of adaptation and adaptive capacity as it is described in the theory of socio-ecological systems. After that, I will present how the concept of adaptation is applied to farming systems and then end with a presentation of some existing research on climate change adaptation of agriculture.

3.1 Resilience and socio-ecological systems

The concept of resilience-thinking originates from Holling (1973) and intends to describe how ecosystems strive towards processes of non-linear stability. More specifically, the resilience approach focuses on the ability of the system to deal with change, recover from shocks, avoiding undesirable states, the capacity to adapt and transform (Folke, et al., 2010; Biggs, Schlüter, & Schoon, 2015). Walker, Holling, Carpenter & Kinzig (2004, p. 3) has defined *resilience* as:

> "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks"

Resilience has been applied to socio-ecological systems (SES) and has been described by Biggs, Schlüter, & Schoon (2015, p. 7) as:

> "the capacity of SES to continue providing desired sets of ecosystem services in the face of unexpected shocks as well as ongoing change and development"

The stability dynamics within SES are explained through the attributes of resilience, adaptability and transformability. Adaptability refers to the ability of actors within the system to influence its resilience and transformability refers to the capacity to enter a new stable state when current system becomes untenable. These characteristics will determine the ability of SES to adapt and benefit from change. However, it also needs to be pointed out that resilience is not always desirable and that we sometimes would want to change a system. This is more common on a larger scale (Walker, Holling, Carpenter, & Kinzig, 2004). An example would be autocratic leadership if we wished to change it into a more democratic society.

The dynamics of socio-ecological systems are determined by its different social and ecological components, their interlinkages and feedbacks between them. The socio-ecological resilience approach view human as an important actor of the SES, which has the capacity to self-organize[6] and adapt based on previous experiences. SES are therefore considered as complex adaptive systems (CAS), which are constantly evolving, shaped by the context of social and ecological factors. Change and disturbance are considered to be important and inevitable parts of SES, as it creates an opportunity for renewal, improvement and reorganization (Biggs, Schlüter, & Schoon, 2015). The dynamics of SES can be described through the *adaptive cycle.* The cycle consists of four phases, which are exploitation (r), conservation (K), release (Ω) and reorganization (α). In the r phase the resilience is high, it represents exploitation and growth and the resources are freely available. As the phase continues into K, it becomes more rigidified the resources are becoming locked up and the system becomes less flexible. In K phase the resilience is low. From this phase a sudden chaotic collapse is inevitable and will lead into a release phase (Ω) where relationships and structures become undone (Walker, Holling, Carpenter, & Kinzig, 2004; Folke, et al., 2010).

Some critique has been directed at Holling's (1973) resilience theory, arguing that it was created originally to describe the behaviour of ecological systems, and as ecological and social systems behave differently it cannot be applied to social systems. However many resilience scholars (Folke, et al., 2010; Schoon & Leeuw, 2015; Biggs, Schlüter, & Schoon, 2015) have argued that social and ecological systems are tightly interlinked with each other and these system need to be analysed in a joint approach. Human actions can be seen as an external driver of ecosystem dynamics, for example through pollution, water harvesting, fishing, etc (Folke, et al., 2010). At the same time, the resilience of SES is partly driven by decisions taken by human actors, therefore humans have the largest capacity to influence resilience of SES. Biggs, Schlüter, & Schoon (2015), however, moves away from a simplistic view of humans as merely an external driver and thus SES can be viewed as self-

[6] When patterns or order arises from interactions and feedbacks between different components within a system, as opposite to outside commands which determines the order of the system (Camazine, et al., 2003).

organizing. Instead they use an integrative approach of actors, institutions and ecosystems across multiple scales that create strong interactions and feedbacks between the social and ecological components which will determine the overall dynamics of SES. This is called *panarchy* (Gunderson & Holling, 2002). Because of this, the system at any specific scale will be influenced by the dynamics of systems below and above, thus affecting its resilience (Walker, Holling, Carpenter, & Kinzig, 2004; Folke, et al., 2010). For example, global or national goals may affect the decision-making on a regional scale. Humans can therefore manage these multiscale interactions to influence resilience on local scale (Walker, Holling, Carpenter, & Kinzig, 2004).

3.2 Adaptation and adaptive capacity

In this section the concepts of "adaptation" and "adaptive capacity" will be addressed. We also need to clarify and separate "adaptation" and "adaptability". *Adaptation* is referred to the mere action or process of adapting or being adapted to something (Oxford dictionaries, n.d). *Adaptability* will be used according to Walker, Holling, Carpenter, & Kinzig's definition (2004, p. 3) as "the capacity of actors in a system to influence resilience". It is important to keep in mind this distinction between the action of adaptation from the actual ability or capacity to be able to adapt throughout the thesis.

In most SES, humans are the main actor who can influence resilience and the one to take decisions about adaptive responses (Walker, Holling, Carpenter, & Kinzig, 2004; Biggs, Schlüter, & Schoon, 2015). Despite that human actors may have a very particular intent with his/her actions, the system as a whole is self-organizing without intent. The self-organizing ability of SES is closely related to the presence of a variety of different components, social or physical, that are necessary to catalyse the adaptive capacity (Park, et al., 2012; Biggs, Schlüter, & Schoon, 2015). This means that as humans influence the system intentionally, but they also generate unintentional effects (Walker, Holling, Carpenter, & Kinzig, 2004). The adaptive dynamic of a SES is an inherent property of the of human-environment relation. Furthermore, the approach to SES dynamics is to allow these components to change and adapt, instead of avoiding and controlling processes of change (Cote & Nightingale, 2012). Darnhofer, Bellon, Dedieu, & Milestad (2010) writes that the adaptive capacity of SES can be improved when actors are able to acquire more knowledge about the components within the systems and their feedbacks, when system is diverse and flexible.

3.3 Applying adaptive thinking to farm systems

There is a growing body of research on the concept of complex adaptive systems and how it can be applied to farming systems (Darnhofer, Bellon, Dedieu, &

Milestad, 2010; Darnhofer, Fairweather, & Moller, 2011; Milestead, Dedieu, Darnhofer, & Bellon, 2012). It departs from the idea of non-static, non-linear systems, and systems as hierarchically nested as was described earlier in section 3.1. A central part of the concept is that change can happen suddenly and that the links between components within a system are important. Systems are seen to be constantly evolving as they adapt to their environment. The basis for adaptive capacity of a farm system is to be able to cope with sudden change and adequately responded to it, ensuring both long-term survival and be able to take advantage of existing conditions to ensure short-term efficiency. To strengthen the adaptive capacity of a farm system, it is required of its manager to understand the flexibility and diversity of the system (Darnhofer, Bellon, Dedieu, & Milestad, 2010).

The farm system is made up of the farmer with his/her social and cultural capital, including mental models[7], preferences, goals, abilities, and so on. The physical farm including land, animals, crops, buildings, finances (subsystems) are the natural and economic capital. Every subsystem undergoes its own adaptive cycle and is therefore semi-autonomous, but at the same time they interact with other systems on different scales and may be affected by them (Darnhofer, Fairweather, & Moller, 2011). Going back to Gunderson & Holling (2002) and the concept of panarchy, the farm system will inevitably be affected by local and global political decisions and market forces which is why the resilience thinking links multiscale interactions into a complex understanding of the system as a whole. To add to the complexity, (Darnhofer, Fairweather, & Moller (2011) suggests that the subsystems may evolve at different pace. For example, rapid change of market prices or consumers' preferences and instead a slow change on farm level.

Darnhofer, Bellon, Dedieu, & Milestad (2010) use the concept of *flexibility* in direct relation to adaptive capacity on farm level. It may be either short-termed in response to a sudden shock or long-termed where choices are made to change the structure and resources on the farm as a reaction to outside influences. There are three factors of flexibility that determines the adaptive capacity of a farming systems. First, the products themselves and their diversity and exchangeability. Second, process on the farm and organisation of work, including technical system which allows these processes to happen. Third are the inputs, for example whether they can be substituted or not. Flexibility is closely tied to diversity (Darnhofer, Bellon, Dedieu, & Milestad, 2010). Building resilience on farm level implies spreading the risks and building long-term sustainability that includes a diversity of co-existing alternatives. This will allow to meet altered conditions more successfully and it also plays an important role during reorganization after a disturbance (see Figure 1, chapter 3.1). It also creates a learning opportunity and protects the farm from management failures in case of climatic stress, by allowing the farmer actively to adapt his/her management and learn about the system dynamics. Diversification of the whole farm may include both on- and off-farm activities (Milestead, Dedieu,

[7] These are based on the person's cognitive structures, upon which reasoning, decisions and behaviour are based. It is used for learning and understanding how and why a person is acting and reacting within a system (Biggs, Schlüter, & Schoon, 2015).

Darnhofer, & Bellon, 2012). Darnhofer, Bellon, Dedieu, & Milestad (2010) calls these long-term choices *strategic flexibility.* A more short-term response is called *operational flexibility*. One important thing to note is that diversity is not objectively given but depends on the farmer's ability to be creative and innovative.

3.3.1 Climate change, agriculture and adaptation

In the AR5 report, IPCC states that "risks of climate related impacts results from the interaction of climate-related hazards […] with the vulnerability and exposure of human and natural systems, including their ability to adapt" (IPCC, 2014a, p. 13). Furthermore, the report states that adapting to climate change "can contribute to the well-being of population, the security of assets and the maintenance of ecosystem goods, functions and service now and in the future" (IPCC, 2014a, p. 17) . More specifically, climate change adaptation is defined by IPCC as: "the process of adjustment to actual or expected climate and its effect. In human systems, adaption seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human interventions may facilitate to adjustment to expected climate change and its effects" (IPCC, 2014b, p. 5).

Research over the years has changed from simple impact approach of direct cause and effect (such as consequences of raised temperatures on crop yields), to include farmers as an active variable that may choose to adapt to agro-climatic change to avoid negative consequences or use it as an opportunity to enhance their agricultural production. Regarding this, different assumptions have been established. On one hand, there is the reductionist view that assumes that a decision-maker has all the needed information to make a rational-choice, that simply because the technological solutions exist that the decision-maker will naturally adjust himself to the agro-climatic changes, treating the decision-maker only as a passive agent of change. The humanist view rejects this notion because it recognizes humans as purposeful and thoughtful, suggesting that farmers would make their decisions based on their understanding of the situation at hand and that the decision-making cannot be assumed in advance. Furthermore, some critique has addressed the human ability to make the "right" decision, even when the knowledge about the situation exists. This is for example the case of long-term decision-making when it comes to risks associated with climate change. Some research suggests that even when there are anticipated losses, some farmers do not have the motivation to adapt to change if they, for instance, have received relief packages from their government in the past. At the same time, even when famers are aware of possible changes due to shifts in ago-climatic conditions and adaptive strategies to address these changes, there might still exist economic, cultural or environmental obstacles that hinders the implementation of such strategies (Johnston & Chiotti, 2011). In other words, there are factors of personality, preferences and competence which influence farmers' choices, as well as external factors such as social norms and structures, technologies and natural environment which constrains those choices (Darnhofer, Bellon, Dedieu, & Milestad, 2010). Some research has shown that not always is the long-term impact of climate change recognized. In fact, some studies tell us that farmers are more concerned with year-to year fluctuations of weather extremes and growing season conditions. While growing season length and its impact on crop production is the more common variable for analysing climatic impact on agriculture, studies has shown that farmers have been more concerned with weather extremes. It is particularly important to consider the short-term weather extremes when implementing adaptive strategies, as agriculture of today is adapted primarily to the mean conditions (Smit & Skinner, 2002). On the other hand, choices made by farmers cannot always be understood from a rational-decision viewpoint such as maximization of profit, because farmers also make decisions based on long-term goals, security, lifestyle and quality of life (Darnhofer, Bellon, Dedieu, & Milestad, 2010).

4 Methods

In this chapter I will describe the methodology of this research. I will begin by presenting the nature of this study and the delimitations of the study area. Then, I will describe the methods and what type of data was collected, ending with an explanation of the data analyses.

This thesis is based on a qualitative exploratory study which uses five farms in Mälardalen, Sweden as cases to learn from concerning how farmers think about adaptation and adaptive management. Exploratory study is done where little or no research exist on the matter and intends to explore the "why" and "how" of the subject. It is also often used to further establish operational definitions, hypothesis or suitable research design. Therefore, it does not intend to generalize but rather give an insight into the subject. Because SES is very specific to the local scale with a unique set of attributes which determines the functionality of the system (Sakai & Umetsu, 2014), it is relevant to study every farm as a separate case which then allows us to learn about the complexity and the nature of a specific system. This kind of research could be done by only using one or fewer farms, but making a deeper investigation of that specific system, applying different methodologies. However, because of the time constraint and timing of this study, it was not possible to do so. Instead, I investigated five farms to be able to make an analysis within and across setting.

4.1 Delimitation of study area

This study focuses on the region in the middle eastern part of Sweden around lake Mälaren, so called Mälardalen. Mälardalen do not have a strict demarcation. It is not bound to county boarders and therefore includes southwest part of Uppland, souteasthern Västmanland, north part of Södermanland and Stockholm. The farms included in this study are located north and northeast of lake Mälaren and are spread across different counties. Beside farmers, I have also spoken with county officials and farmers' organisations from Uppsala, Södermanland and Stockholm county.

4.2 Review of literature and official documents

Prior to the interviews, I did a literature review with focus on resilience, adaptation, socio-ecological systems and farming systems. Additionally, I reviewed official reports and documents which addressed climate change impacts on agriculture in Sweden. The documents provided the basis for my interviews as they helped me to formulate relevant themes and questions that would be used during the interviews. It was necessary to understand the general context in which these farms operate, as well as specific threats and possibilities of climate change in the context of Mälardalen, Sweden.

4.3 Interviews

Method used in this study are interviews. I used both in-depth interviews and semi-structured interviews. I started by thinking of certain themes that I wanted to cover. These themes were covered for the most part with all the interviewees. Based on the themes and my research questions, I formulated interview questions around these themes. The questions were based on the themes but had to be adjusted and reformulated depending on if the interviewee was a farmer, a representative from county administrative board (CAB) or farmers' organization. This allowed me to ensure consistency across all interviews by using same themes but somewhat different questions which in turn would make data analysis easier and more coherent.

A total of nine interview were conducted (see Table 1 and Appendix 1 for more details). Majority of the interviews were done face to face, but three of them were done by phone. The reason for this was that some interviewees preferred to do it by phone rather than meet up (duo to time constraints). Most of the interviews took around one hour, except those done on the phone which were between 20-30minutes. I was also constrained by the fact that most of the included case farms were only accessible by car and my lack of transportation.

All except two phone interviews were recorded and then transcribed. The interviewees were asked beforehand if I could record them. It was promised that their names would not be used in this paper and that nobody except me would be listening to the recordings. Because all farms used in this study are family farms, to ensure their anonymity, the names of the farms will not be used in this paper as it would easily disclose their owners and thus, their identity. The farms in the study are therefore named Farm A to E (see chapter 5.1 and Appendix 1 for a closer description of the farms) and the farmers will be referred to as Farmer A to E. Additionally, I interviewed farmers' organizations and county officials to gain a more general understanding of adaptation of agricultural sector. Likewise, their names are not going to be disclosed.

4.3.1 Sampling

Initially, the geographical delimitation of my study area would only include Uppland province. I did not want to delimit myself to any specific type of production, e.g. only crop production, meat production or diary production, nor any specific farm size (small or large scale), since the study would be exploratory. I started contacting different farmers in Uppland in the beginning of March, but none of the farmers that I could find would agree for an interview and I had to expand my area of delimitation. In the end, the contacts of all the farmers that participated in this study, were provided either through family contacts or from other interviewees. Therefore, I did not know beforehand what type of production the farms had.

4.4 Data analysis

The interviews were analysed by using template analysis as it is prescribed by Sang & Sitko (2015). Analysis started by identifying themes prior to the reading of the transcribed interviews. These themes were partially framed by the theoretical framework and background and some themes emerged from the interviews. Codes were assigned to themes, which then were assigned to parts of text. Some new themes emerged during the first text analysis. After reading through all transcriptions a second time, sub codes were developed, and all codes and sub-codes were hierarchically sorted. The final step was to apply the template of codes to all the text. This final step was especially important for the final analysis of data and writing of the results. First, it was easier to identify parts that, although being interesting, were not relevant to my research questions and could therefore be excluded. Of course, this was already done during the first reading process of all the data, but the final step helped further with this process. Second, it was often the case that two or more codes or sub-codes would overlap with same portion of text. I found this to be especially interesting because it created some connections between data that might not have been recognized without the coding. This was very important for the final analysis and presentation of the findings.

5 Findings

This chapter will showcase the analysed data which was collected from the interviews. I will begin by giving a short description of the farmers that were used in this study. After that, I will present some general findings about climate change adaptation discourse and the effects of drought in summer 2018. Then I will go more into the specifics of the different farms; how the farmers think about climate change and climate change adaptation and their reasoning around adaptive management on their farms. Lastly, some important aspects of self-sustainability on farm level will be discussed.

5.1 Introduction of case farms

The farm cases included in this study are all very different from each other both when it comes to scale and type of production (see Table 1). However, they also have a few things in common. They are all family farms and specialize in livestock keeping, either for milk or meat production. All of the farms also have crop production. A majority of this crop production is fodder production (mainly grain crops and green fodder, including ley production) for their livestock with the exception of Farm E which also cultivates a large area of grains to sell. They all vary in farm size and size of livestock. All farmers are used to dry conditions, since the study area (northern part of Mälardalen) is typically dry during the early summer period, but their biophysical surroundings create different conditions and opportunities for these farms to deal with it which will be explored below. Since these farmers are used to a dry early summer, the findings have shown that they were to some extent already adapted to the drought that ravaged in summer 2018. All the farms have both animal and crop production, Table 1 is therefore sorted by main production type of the farm. For a more detailed description, see Appendix 1.

Table 1. *Description of farms from the study sorted by the main production type.*

Name	**Type of production**	**Livestock size**	**Total area of cultivated land (ha)**
Farm A	Beef meat	22 suckling cows	40
Farm B	Beef meat, egg	35 suckling cows 4000 chickens	150
Farm C	Milk	60 milk cows	350
Farm D	Milk	150 milk cows	150
Farm E	Milk, wheat	100 milk cows	460

5.2 Threats and possibilities with climate change

The anticipation of climate change impacts and threats varies greatly between the interviewed farmers. Some see climate change as a threat, while some do not consider it to be a threat at all. Two farmers from the study envision that a changing climate will bring new opportunities, such as the ability to cultivate new crops. Whereas the representative (who is also a farmer) from Ekologiska Lantbrukarna - a farmers' organisation for ecological production – states that there is of course a concern within the organization about the changing climate and what these changes might bring in the future. The general threat perceived by Ekologiska Lantbrukarna are the extreme weather events, particularly if it would happen several years in a row. One difficult year might be tough but surmountable, while having extreme weather events several years in a row would make economic survival extremely challenging. Overall, the organization believes that the climate change threats should be taken more seriously when it comes to its impacts on agriculture and attempts to minimize the risks should be made, although it was never expressed specifically by whom. Similarly, the officials from CAB and representative from LRF have expressed that agricultural production in times of climate change is an issue that needs to be taken more seriously.

On several occasions it was mentioned during interviews with CAB and LRF that an older generation of farmers are not being as worried about climate change as the younger generation (age of 30-40). And since the agriculture is dominated by an older generation, this might leave an impression that older farmers might care less about climate change adaptation as well as being less open to new ideas. This is of course a valid point considering that there might be an uncertainty whether someone will take over the farm after a farmer's retirement, which might make long-term investments not much attractive. CAB and LRF suggest that some people might not see the need of certain necessary investments when they cannot see how it will benefit them. It also comes down to whether the investments can be seen as profitable long-term or not. Agricultural production, like any business, needs to be attractive and profitable to get people to work in this sector.

5.2.1 Climate change adaptation or climate change mitigation?

The discussion of climate change adaptation in Sweden has been very limited until recent year, although the government started the discussion already in 2015, most likely as a result of IPCC (2014) report and the Paris agreement in 2015. There are some strategic action plans for climate change adaptation in agricultural sector that has been brought up primarily by SJV, but otherwise there has been little discussion on the official level according to CAB. One of the main official strategies to spread the information about climate change adaptation and climate change mitigation is through different courses held by LRF, SJV and CAB. However, the debate is still much focused on climate change mitigation and how to reduce negative impacts on environment, rather than the adaptation. However, the officials and organization representatives have suggested that it is a grey-zone between these two categories as several mitigation strategies could be considered as adaptive strategies (see more in chapter 5.4.1). The goal of all these organizations and courses is to spread the knowledge to farmers about environment, water, climate etc. An example of this is currently undergoing study circles held by LRF to teach more about water savings. Another project that is run by CAB, called *Focus on Nutrients* (Greppa näringen) which primarily deals with reduction of nutrient leakages and use of crop protection products. There is no expressed goal or strategy within Focus on Nutrients that focuses on climate change adaptation, but it provides information about several aspects that are relevant to this matter, such as soil fertility, increased energy efficiency on farms, drainage and so on. The officials said that it is sometimes difficult to attract farmers to these meetings and courses that are held by CAB and that the interest varies greatly. Usually, there must be some economical incitement to make the courses attractive.

5.3 Drought impacts on agriculture in Mälardalen in summer 2018

After the first harvest in 2018, the largest concern among the farmers around Mälardalen was that there would not be sufficient amount of animal fodder to last throughout the coming year. LRF arranged meetings with hundreds of farmers to discuss this matter, but also to start up a dialogue with insurance companies, banks, etc. Luckily, the consequences of the drought 2018 were not as bad it might have been anticipated. In August, the rain finally came and most farmers were able to get one (or even two) grass harvests that year. But it came at a great cost. The result was of course that the prices on fodder and grains went up, so it could arguably be said that it to some extent compensated for the harvest losses and thus economic losses, however only for those growing cash crops or selling surpluses of animal feed. For

Farmer E the case was reversed. Instead, he had to pay 30-40% more for fodder throughout the following year. Most of the farmers in this study that have livestock usually produce all their fodder for themselves (except for protein fodder). For them, the higher selling price would not be something they could benefit from. However, what made a clear difference in 2018 was the increase in working hours spent on harvesting, diesel costs and the wage for the time put into extra working hours. Indeed, Farmer B told how they had to struggle through the whole summer to collect enough fodder, working long hours for little in return and disproportionate salary.

However, the drought itself was merely one part of the problem for farmers in summer 2018. Combined with the increase in temperature, the heat made it even harder for crops to grow. In some places it was so dry that only 30% of the crops had germinated by June/July. Even when it was possible to irrigate some crops, the evaporation from soil was too fast to make any big difference and the temperature was too high which stopped crops from growing. At the same time some streams and groundwater were affected as well. There were some ground water shortages where wells were completely dried out and some farms were not able to get water for their animal. Similarly, summer 2017 was considered a relatively dry year as well but did not have the same high temperatures as the following year. This allowed the crops to grow more normal. But in autumn 2017, the rain came in August and the following two months were very wet instead. This caused some farm land to become too wet for the machines to be able to drive and sow. Instead, the autumn sowing got delayed and some farmers could not sow their lands until spring 2018. This in turn made the situation in 2018 even worse, since there was no autumn sown harvest to take from.

The fodder shortages forced several of the farmers all over the country to take the decision to decrease their livestock numbers. The queues to slaughterhouses built up as many farmers did not think they would have enough animal fodder to last through winter. Farmers in Mälardalen, however, managed to avoid this problem and could find the necessary feed anyway, even if it meant working long hours on pieces of land with low productivity. The fodder shortages had a greater impact on horse owners that often do not own any land. Many of them were desperate to find fodder for their animals and had to import a lot of it themselves, according to LRF and CAB.

5.3.1 Political support in case of climate crisis

One important factor that made it easier for the interviewed farmers and others to deal with drought in 2018, was that SJV gave dispensation to use some of the land that was lying as fallow, which under normal circumstances would not be allowed to be harvested or grazed at that time, according to the CAB regulations. This decision came very quickly after LRF pushed the issue to the CAB and SJV. Some additional support was provided by CAB in some of the counties in Mälardalen by opening grazing agencies after the drought that would mediate available grazing lands and livestock in need of grazing. A Facebook-group called Foderhjälpen 2018-2019[8], grew to 26 000 members, and it started to mediate fodder availability between farmers and other land owners.

It has been expressed by LRF that there is a need for more collaboration between different governmental agencies in the case of crises. As it is now, the roles are very defined within government, which affects the perceptions of responsibilities within different governmental agencies. The role of CAB is to make sure that involved actors meet and collaborate, but LRF thinks that more could be done by CAB. Especially in case of crisis there is a call for collaborative actions between more agencies.

The farmers in this study were not only worried about possible extreme weather events in the future, but also the political situation tied to climate change and agriculture in general. Most of the interviewees expressed a concern of not being taken seriously enough by the government, as well as a general lack of understanding by both politicians and consumers.

"The political commitment is a security, because we are dependent on government support and grants". – Farmer B

"What you really can do in Swedish politics, is to change the mentality. We are the only country in the world that sees agriculture as an environmentally hazardous activity. It feels so wrong at the bottom of the heart […] other countries are so proud of their production and open landscapes. It [the mentality] takes away some of the pride. What we do is an incredible environmental contribution[9]". – Farmer C

"Decision-makers have the same skewed view [as the consumer] about reality [...] so it is our biggest challenge in agriculture that people take us for granted despite that farmers quit on daily basis in Sweden". – Farmer E

The remaining crisis package that was supposed to be handed out in 2019 has still not been payed. The delay is due to an internal discussion within SJV concerning how to distribute the money. The first package in 2018 went out to all farms with grazing animals[10], but not to those who cultivate ley.

"It is imperative that the crisis package is payed. The liquidity is strained now the year after the drought, because much of the costs happen during the winter when one is ordering fertilizer, diesel and so on. It is from now on and forward that I believe it will be difficult for some". – LRF.

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[8] Meaning 'Feed Aid' in Swedish.

[9] Farmer refers to grazing done by cows, which he suggests keeps the photosynthesis constantly in work and therefore makes a source for carbon storage.

[10] In 2019 SJV changed some of the directions regarding who would be entitled to receive the crisis package, now also including pigs and poultry as well as specific crop producers. The money is expected to be given out starting in July 2019 (Jordbruksverket, 2019).

The farmers participating in the study did not feel that the crisis package from the government made any bigger difference but were still thankful for whatever they received. The losses which farmers had due to the drought, were estimated to range between 0,5 million to 1,5 million SEK for different farmers. These estimated losses included decrease in the production and selling of crops, as well as decrease of milk production because of negative impacts from high temperatures on the cows' milk productivity.

5.4 Investing in adaptive management

Things such as change of crops and crop rotation, species composition in ley cultivation were discussed during the interviews. However, because of expected fluctuations in weather extremes it is hard to determine which strategic adaptive actions are the most suitable to implement. Many of the interviewed spoke of the drought of the summer in 2018 as a very tangible experience of how things might become in the future. However, the LRF representative was cautious against focusing too much on drought resistant crops only because of one extreme year. On the contrary, the long-term scenarios tell us to expect more wet weather extremes. It is therefore imperative to try to find crops that could withstand both dry and wet weather conditions. This would require more research on both technical aspect of farming as well as breeding of alternative crops. The suggestion of collaboration between farms as a strategy was also been put forward several times. In chapter 5.4.1 and 5.5.1 I describe some of the specifics that exemplified this strategy during summer 2018.

5.4.1 Irrigation and drainage

The possibility of irrigating farm land during summer 2018 and irrigation as a future strategy against droughts was discussed with all the farmers. Currently, the irrigation systems are very costly and none of the farms in this study has an irrigation system but manage their land as rain fed land. Because it is very costly, irrigation is rarely profitable unless it is used for specific crops such as potatoes, carrots and some other vegetables, which are not extensively cultivated in the study area. Irrigation practices are more common in the southern part of Sweden. After the summer 2018, there were rumours that some farmers had invested in a water plant even in the study area. It has been suggested as a strategic investment to irrigate the grazing land closest to the barns, especially for the farms specialized in milk production. The reasoning is that by irrigating the pasture land closest to the barns, the cows do not have to walk very far during grazing season. This reduce the need for additional support feeding and if they walk too far, they might not be back in time for milking.

Both LRF and CAB discussed the importance of ditches. To have a ditch connected to farmland might serve several purposes, such as decreasing the leakage of nutrients, but also as an important strategy for drainage and to deal with extreme rain events. Many of the ditches in Sweden today were built by the end of 19^{th} century and beginning of 20^{th} century and have not been maintained but let to degrade. Both LRF and the CAB work with spreading the knowledge about advantages and usage of ditches. But there is a lot of regulations and the maintenance which makes ditches a relatively unpopular operation. An additional aspect that makes ditches complicated is that they are often built as commons and therefore requires collaborative management between neighbours and many are afraid that it will become a potential conflict.

5.4.2 Economical incitaments

One central issue of climate change adaptation is of course the costs for certain strategic actions and implementation and who should pay these costs. One such example was mentioned in previous chapter; irrigation systems that are too expensive to be profitable for the average livestock farmer in Mälardalen. Generally, the profit margins in agricultural sector are very small and that leaves very little room for large investments, even during a good year. But it is also an important question on every farm, what they choose to invest in and on what level. Most of the interviewees implied that the current food prices are too low and that it would be better for the agricultural sector if the prices on food would increase. During 1970s when the prices of grain were much higher, it was possible to economically justify investments in irrigation plants. Still, some of those irrigation plants remain since the 1970s, unused. Even though it was probably justifiable to use irrigation in 2018, all the years before that it would not have been so, LRF representative tells, while Farmer C spoke of the uneven development between fuel prices and milk prices since the 1980s, when the milk prices and diesel prices were about the same. Today diesel cost around 15-16SEK and milk costs 3,30SEK/l[11]. If the prices for milk would be higher, the farmers would have much higher margins. Several farmers implied that the financial support (mainly from EU) is there to keep the food prices low for the consumers, but that it has negative impacts on the agricultural sector and for the farmers by creating such small margins. At the same time, it creates a concern among farmers, because they are so dependent on this support. Another suggestion given by LRF was that the costs in the case of crisis such as last year, would have to be spread across the society as a form of civil defence rather than crisis packages during. Crisis packahes might save some smaller agricultural business but do not bring much relief in general.

[11] What is actually payed to the farmer and not the milk prices in stores.

5.5 Diversity and flexibility – adaptive management strategies on farm level

5.5.1 Operational flexibility – short-term solutions during drought

All farms in this study experienced hardship last year, some more than others. Most of the farmers did sow three times in 2018. Farmer B got his first harvest almost normal and the last one in August was good, but during summer the production was almost non-existent. He decided early that summer that they had to create a special budget for additional expenditures on fodder. His budget was 100 000SEK, but in the end the extra expenses for fodder turned out to be double. This did, however, not include the costs for diesel and salary for extra working hours. He had to press straw on others' land that he then could buy to use as fodder. He was not alone in doing so. Also, farmer C, D and E experienced large fodder losses as well and only got around 50-60% of their normal harvests (both in grain and ley). It took many extra hours to scrape together all available fodder on other people's land during the summer. But for all of the case farmers, the rain in August allowed them to have a good third harvest.

When speaking of flexibility and diversity on farm level, the discussion has often been about how to adapt and optimize the usage of land acres. Most farmers have a certain flexibility in their cultivation and how they use crops and ley. This means that they take active decisions on what to do with the land and how to manage their crops. For example, Farmer C says that they produce grain to sell but also to use it as fodder, but on a dry year such as last year, or in case of other crisis, the solution would be not to sell the grain but use it as fodder. He also keeps a fodder buffer of ley and hay (they press their own hay bales) which would suffice for at least a few months. A bigger problem would be if they had a power cut. It would prevent them from crushing grain to make fodder, but once again that is compensated by the fodder buffer of hay bales. Instead, the farmer recognizes milking as a much bigger problem. Most farmers (and officials) suggests acquiring more land as a buffer to ensure that they can cultivate enough fodder during a year of climate crisis. Farmer C suggested to use larger percentage of available fields for ley production (instead of for example growing grain), while Farmer E disagrees with the idea that acquiring more land is the most viable solution if summer 2018 was to repeat itself. He argues that the choice is either to acquire more land or intensify the yield on the existing land by, for example, experimenting with new drought resistant crops. It would be better to get a decent yield from existing acres rather than low yield from a larger piece of land, he argues.

Not all farmers that participated in this study were forced to buy fodder last year. Farmer A tells that she was even able to sell some of her fodder to others. The reason for this was that her land is large enough to support a double number of livestock than what she has at present. When she started working in agriculture in 2017, that year was also relatively dry. It made her cautious and she did not expand her livestock numbers as she had originally planned. Her farm area could therefore provide her with more fodder than was required to be selfsustained. This combined with the fact that she received 70% of her regular harvest, gave her a surplus of fodder. Farmer C was faced with a similar situation, where circumstances made the situation in 2018 easier. That is, he was also planning to expand his farm, going from 60 milking cows to 140 cows. But this had not happened yet, so despite that they only received 50% of their harvest that year, they had sufficient amount of fodder, which of course would not been the case if they had expanded that year. Farmer C was also selling some of his fodder this year to those who still needed more feed for their animals. One farmer suggested to lower the livestock number in case of persistent fodder shortages. He said that he would survive all year round on his own production that way. Fortunately, he did not need to do so during 2018, but he made sure to book the deliveries to the slaughterhouse several months in advance[12]. Farmer C explained that it is a decision that needs to be taken early and many farmers who only delivers once or twice a year instead of on a regular basis, often do not plan that far ahead.

One of the issues in 2018 was that the slow growing pasture lands were not sufficient for the cows during grazing seasons. Therefore, the farmers had to feed them with supplement roughage inside the barns. Some farmers also experienced that the cows were not feeling well during the heat, especially the milking cows. In case of Farm C, the cows were allowed to use forest land as they prefer to stay in the forest and its shadow. Similarly, Farmer A also have some forest pasture that gives some shelter to her cows.

5.5.2 Strategic flexibility - planing ahead

Both farms D and E grow maize and it gave a good result even during the drought in 2018. On Farm E, the roughage consists approximately of 25-30% maize and the maize gave about 90% of the normal harvest that year. The maize production has existed prior to the drought, because the area is relatively dry, farmers have been experimenting with drought resistant crops. Several of the farms also mix lucerne in their ley cultivation, a plant which also is drought resistant.

Some of the farmers talked about expanding their number of livestock, but they all have different reasons for that. Farmer C, who has milk as the main production, do not have any milking robots, meaning that all the milking is done mechanically with milking machines. Because they are only two people working on the farm, this have been negative for their health. The plan is therefore to construct a larger barn with milking robots to relieve some of the work load from the family. Currently the situation is very strained between the Farmer C and the bank, because the farmer does not want to have a too large livestock size. He wishes to have around 80 cows

[12] Fodder shortages in 2018 caused many slaughterhouses across the country to be fully booked one year in advance.

with two milking robots, but since a new barn requires high investment cost and loans from the bank, the bank pushes for an even larger livestock size than 140 and more robots to make the investment pay-off. Additionally, they would need to hire workers instead of doing all the work themselves. This is not something that interests the farmer. Firstly, because he does not want to become an employer. His interest has always been the cows and he was never comfortable working with a large herd. For this family, a personal contact with cows has always been important and they are treated more as pets, all having own names (even the new born calves get a name). Secondly, he believes it might not be a strategic option if there are more years such as 2018 to come, because it would implicate larger needs of animal feed, something that could become very expensive and leave them with lower margins.

The concern of the farmers in this study for the climate change varies greatly. Some are concerned about extreme weather events and the impacts these may have on their production, while others feel that they have prepared for what might come. A few have expressed that they do not think the climate change will have any larger impact in the nearest 50 years or so. Some have emphasized that weather variations and extreme weathers happen naturally, and that last year's drought might have little to do with any climate change at all. The chance to sow three times a year instead of two was discussed and most farmers see it as a possible opportunity for the future. However, not all agree on this notion. Farmer D has adapted his harvest to three times a year since he expanded the farm in 2006, but he tells that many farmers in proximity still only have 2,5 harvest a year and use the more traditional crop species. Farmer E does not perceive that the growing season allows them yet to make a third harvest. He considers it to be an emergency solution like in 2018, because a third harvest[13] does still not yield very much. As for the future, he would consider growing a third crop, depending on the needs of that particular year.

Some problems and opportunities with technical solutions were discussed. Most, but not all, barns in this study are relatively old or have been only partially renovated. A majority of the farmers want to either replace or build another barn. Farm C has an old barn where the cows are tied and therefore cannot walk freely on their own. If they buy/construct a new barn, it would be built to allow the cows to move around freely and to go in and out as they please, for example during the night when the temperatures are lower. This strategy in combination with the forest land that they can use, would relieve some of the heat stress during summer. Some of the barns were old and did not have any possibility to open the sides of the barn, which would otherwise make the heat inside much more bearable. Another problem recognized was that the ventilation was not sufficient in some of the barns.

A discussion of storage capacity was raised. A majority of the farmers said that they could store and be self-sufficient by using their own energy fodder from 6 up

[13] Discussion about a third harvest refers to cultivation in-between spring harvest and autumn sowing, normally during summer or possibly sowing a fast-growing crop early autumn to get one yield the same year.

to 12 months. Ensilage is easy to store and can usually be stored up to one year without losing too much of its quality. Some of the farmers use to save a portion of their roughage to have some margins in case of emergency, but at the same time they expressed that it is not economically viable to have too much fodder stored. Some years it might be needed, while others it is not even possible to sell, and it gets completely wasted instead.

Several interviewees suggested that a diversified livelihood would be an important strategy to minimize their vulnerability. That includes having some side-business or entrepreneurial work. It would hopefully bring some capital and savings that can be used in case of crisis. Because the profit margins from agriculture are small, it makes it difficult to have any extra savings. Some also spoke of more diversification on farm level. For example, farmer B had suckling cows and the calves are delivered to the slaughterhouse during the spring season and some during beginning of autumn as well. He considered this as a vulnerability of the farm and wished that he would be able to provide meat all year round. This can be done by purchasing and raising heifers and then sell them during late autumn. But that would also require a new barn and additional land. He was hoping that he will be able to purchase some land from a neighbour soon so that he can expand. Diversification was also a reason why they have started with egg production. It was integrated in the farm as a way to improve the liquidity and to diversify the incomes.

5.5.3 Biophysical advantages and disadvantages

Some biophysical advantages and disadvantages played an important role for the farmers during the drought in 2018. Farmer C tells that one thing that saved his fodder production last year, was a piece of land that used to be an old lake bottom and is now an area of moss soil. It is normally very moisty area, even during a dry summer, so nothing can normally be sowed there. But last year it was dry which made it possible to drive on the land with tractors and to sow. Approximately half of all his harvest from that year came from this piece of land, no more than 15 hectares. The other half came from 100 hectares of his regular land. In the case of Farm A, the harvest losses in 2018 were not as large as for some other farmers. They received around 70% of their normal harvest. Farmer A believed that it was mostly due to clay-loam soils in this area, which has good water holding capacity.

The possibility of future irrigation depends of the biophysical context. Most of the farmers do not have any water nearby and their possibility of irrigation would be very restricted. Access to water is therefore an important biophysical factor that may affect adaptive capacity of the farm. Farmer C tells that several farmers nearby have been applying for licence to build a dam, but personally he found a better solution. Seeing how he had a success with the moss soil during the drought, he has now applied for a lease of additional 80ha of same land area. It is much more efficient than building an irrigation system, he stated. But one of the interviewed farmers has now invested in an irrigation plant as a result of last year's drought. Farmer

E is located not too far from lake Mälaren and it was the reason why they decided to invest. He says that without good access to water, building for irrigation is difficult. It might require the use farming land to build a dam. He felt that they are lucky for having such a proximity to a water source. He also argues that the investment costs will be paid off in two years. Another farmer has considered to build a water dam in adjustment to his ley cultivation. But his problem is that his land is divided in several parts which makes it unpractical to irrigate, so it would require building two dams. Overall, the cost for such investment would be high and would probably require cultivation of some cash crop. Farmer A has several wells on her land and some have not been used for a long time. She says that the wells on the farm land has never dried out before. She will make sure that the other wells continue to work as a backup strategy in case of future water shortages. This water is only used as drinking water for animals and not for irrigation.

Farmer B has considered to cultivate maize in case the climate gets drier. He has tried cultivating it before. However, the soil quality is not quite right for maize cultivation on his land. Additionally, he has problems with wild boars in the area. He has tried to cultivate some maize before and also some pees, but it got destroyed by the boars.

5.5.4 Off-farm activities

All interviews use some other sources of income in various degree. Some of these are jobs outside the farm. Others are entrepreneurial jobs closely connected to the farm, but nevertheless provides other sources of income. One of the farmers have a steady job outside the farm. Farmer A only works around 25% on her farm. Her main job is with a consulting organisation that works with rural development and agriculture. Therefore, her main income is not coming from agriculture, but from her external employment. She works on the farm mainly in the evenings and on weekends. Sometimes her husband helps her with the farm during weekends and her father also still works on the farm.

Most of the other farmers do some contract work on other farms with their tractors. Farmer B also works in Stockholm during winter, plowing snow with his tractor. One thing that makes him a bit worried about climate change, is that a warmer temperature may leave him with less or no work to do during winters. All farmers that have their main occupation on their farms said that these types of entrepreneurial jobs are done to improve their liquidity. Farmer C sometimes also does some work on other farms, as well as being a musician and doing some performances couple times a year. However, compared to the income he gets from the farm, this additional money that he earns is relatively small, he says. Another problem is that they are usually two people working on Farm C and when one person is gone, that leaves a much heavier burden on the other. This is something they try to avoid.

Some of the farmers also own some forestland adjacent to their farms. But only Farmer D uses it for commercial purposes as another source of income. Farmer C, who originally had 25 hectares and recently acquired more forest land (now he has 55 hectares), tries to do some forest farming, but does not use it for any other commercial purposes. It is only used to acquire some firewood. Having some sort of forest production would require a lot of extra work, he says, as the forest must be cut and rejuvenated.

5.5.5 An example of local entrepreneurship

Farmer B opened a farm shop 10 years ago and it is a concept which has been under continuous development ever since. The shop is located on the farm land and the idea is to provide consumers with good, locally produced meat. Approximately 25% of all his meat production is sold in meat boxes in this local store, but he wishes to expand his business. One of the biggest challenges is to find options for marketing. They have a website, a Facebook- and Instagram page as one way of promoting the shop. Otherwise, he believes that acquiring new customers through the regular customers is the best strategy. There is one problem to find the right clientele, however. All the meat boxes that are sold are approximately 25-30 kilos meat. It is difficult to find clientele that would be interested in that much meat at once. The idea is that every animal should be cut in half so that every box contains equal meat cuts. This is very just, he says. However, they are thinking of potentially changing into other types of meat boxes. Currently they have a few one kilo packages of mincemeat for sell in store. Additionally, they also sell sausages, which are done by another entrepreneur using meat produced on Farm B. Some of the eggs are also being sold in their store. He noticed that the meat consumption has been reduced over time. In his case the farm shop has got an increased clientele, but the amount of meat that is purchased is about the same because people now seem to buy less meat. All the customers have to visit the store to buy their products. It is a concept that is emphasized, because this will create a closer relationship to the farm and to his customers. However, in some rare cases they do home deliveries without taking extra charge. Another way of increasing his sales is through a collaboration with a local wholesaler who used to only have imported meat until recently. Since many consumers are interested in locally produced food, the wholesaler has been emphasizing that this particular meat is produced on a nearby farm. Farmer B is very proud of his meat and its quality. Therefore, he sees this as a very good and fun opportunity.

> “Our meat is way too good to just disappear into a black hole”, he says.

He hopes this will promote his own local store sales. Of course, he prefers to sell directly from his own store, because he enjoys the interaction with his customers.

5.6 Self-sustainability on farms

Self-sustainability is one aspect that may play a crucial role in case of crisis, whether it is due to sudden weather extremes, market fluctuations or political decisions. Arguably, self-sustainability on farm level leaves more room for adaptative management, which I will later be discussing. But what sort of self-sustainability are we talking about? In this study all farms were specializing in livestock (meat or milk production). There are two main factors that are required for the farms to function and on which everything else in the end falls back to. The first is availability of livestock fodder. The second is fuel. In the first case, all farms were producing their own roughage and could therefore be seen as self-sustainable in this aspect. But all farms still have to buy protein fodder as supplement. As for the second aspect, unfortunately all farms depend on fuel for their tractors that are required to cultivate and harvest their land. Some of the strategies that could lead to a higher self-sustainability were discussed and will be showcased in the next chapter.

5.6.1 Fodder supplements

Fodder supplements (mainly high protein concentrate) was discussed with all farmers as it is necessary to ensure fast growth in animals, especially in the young ones that are raised for meat production. Protein supplements are also necessary for the milking cows. All farmers from this study have to acquire supplements outside of their farms. In the case of Farm A, the protein supplements is bought for the young calves. The farmer has considered to grow her own protein fodder (field beans and peas) to make the farm completely self-sustained on animal fodder. However, she has not yet made any decisions. First, the farm does not have the right equipment to mix this kind of fodder to get the right texture. A second reason is that she would have to replace some of the area that is used for cereals to cultivate protein crops. That means that less crops would be used for commercial purpose. There is an economical reasoning behind it and she tells that the costs need to be calculated and compared before making any decisions. Farmer E has a similar reasoning. Cultivating own protein crops would require him to set aside some of the land used for crops that are used as cash crops, so as of now he prefers to buy protein fodder instead. But some of the farmers use lucerne in their ley cultivation. Except being a drought resistant species, it also provides more protein in the ensilage. Instead of using a traditional mixture of clover and grass, which only gives energy fodder, including some lucerne in ley cultivation allows to purchase less protein supplement.

On Farm B, approximately 10% of fodder consumed by young calves is protein concentrate. Historically, the farmer used to buy protein pellets from an ethanol factory nearby. All the energy is extracted from the grain, leaving a residue of a high protein pellet which works well as a supplement. Farmer also says that the animals like this taste as they get tired of eating their regular fodder. But previous year, the fodder was not available for purchase, so he had to buy regular protein concentrate.

He tells that he does not like to buy soya-based protein fodder because he does not want to have imported soya in his fodder. The only exception is fodder which is used for his laying hens. Their fodder contains 65% grains from own production, 35% protein concentrate (soya-based) and 5% lime. He says that he is very satisfied with this mixture, because it has a good impact on productivity of the hens, even though he wished that he could use soya-free protein. But at the same time, costs and availability must be considered when choosing supplements.

Overall, all of the farmers were against protein concentrate which is based on imported soya and tried to buy fodder made of Swedish products. For example, Farmer C must also purchase protein supplements for his milking cows, despite that he cultivates some pees on his own land. In his opinion, it is important to support the production made of Swedish products. He says that it is much easier for him to buy supplement (that contains 100% Swedish raw products) from others that specializes in this production himself.

> "It is both easier and saves me lots of work and trouble. It is much safer for me to cultivate grain and sell it, then buy protein fodder from farmers that specializes [in this type of production] and are much better at it than me". - Farmer C

Furthermore, the same farmer talks about how recent suggestions have been made that the first ley harvest should be done late in May, when the grass is still brittle and contains much more protein. He tells that if he waits another 14 days, the grass will be much taller, and he will get twice as much fodder (although containing much less protein and more roughage) for the same amount of time spent on harvesting. All in all, it would be more efficient to let the grass grow taller and buy protein fodder instead, the farmer is convinced. If he would harvest it earlier when the grass is still low, he says that he would not need to buy almost any protein supplement, but he would need to use a larger area of land for lay production instead. That means he would also need to use more fuel, which then leads to more carbon dioxide emission and leaves a larger negative footprint on the climate. Additionally, he tells that he would need to mix it out with hay because otherwise the fodder would upset the cows' stomachs. Generally speaking, the farmer is experiencing an ideology that dictates how feeding cows with roughage or grains is regarded as something negative and that many farmers use the sales pitch that their cows only eat grass.

> "But the cows love to eat cereal and roughage. It's as when we eat candy or popcorn. 'Don't you let your cows eat some candy?', I ask them then. Fresh salad can be tasty, but sometimes a little bit of popcorn tastes good as well". – Farmer C

5.6.2 Fuel

One of the largest aspects that makes agriculture in Sweden vulnerable is fuel. This is recognized as a problem by most of the farmers. Diesel is necessary to make the farm function. You need diesel to drive your tractors and to milk your cows. Without it, the modern agriculture would not be possible. Yet, fuel is very expensive and is a large cost for the farmer. At the same time, there are almost no or few diesel-free alternatives. But some of the farmers and representatives expressed that the fuel issue is mostly a political problem. One suggested that the government has little interest in developing biofuel because the taxes on diesel are so high[14] that the government do not wish to invest in the alternative, seeing it as a good source for tax. The largest ethanol factory in Sweden that makes fuel for vehicles is located Norrköping, but all the fuel is sold off to Germany because prices there are better. There is currently no expressed strategy on the official level to invest in cultivation of biofuel crops, according to LRF.

The matter of specializing in crops for biofuel was discussed, but very few farmers seemed to be interested. One reason for this was because of the general belief that biofuel is not profitable (high crop refinement costs and low demand for biofuel crops). A governmental investment and support for biofuel production considered needed, as it is now cheaper to produce some diesel than certain biofuel. Several suggested that forestry would make a better source for biofuel production than using farmland. Farmer C had a different view, however. He suggested that growing crops for biofuel would make the better portion of crops go to food production and the lower quality ones go to biofuel production, thus increasing food quality in stores. But the farmer can never become completely self-sustainable in terms of fuel, because it has to go through refineries first. One argument that is sometimes used for not cultivating biofuel crops, is that it would compete with the land used for food production. Farmer E expressed this and said it would lead to less food for the consumers. The contra argument used then is that prices of diesel and oil are so high that it would not make any sense not to invest and develop a biofuel production. Another argument used was that if we look back a hundred years or so, then the notion of producing fuel on farm land was a standard practice during times when people used horses for ploughing and harvesting, and farm land provided grazing and hay as a source of energy for the horse. Therefore, it should not be considered as a controversial matter. The LRF representative suggested that there is enough old, unused farm land that can be used for biofuel cultivation so that it does not have to compete with other food production. The downside is that this land is normally less productive, which means that using it would not be very profitable.

[14] The prices on diesel fluctuate, but recent number from February 2019 shows that the tax was almost 50%. This including VAT, energy- and CO_2-tax (Holmström, 2019).

6 Discussion

In this chapter I will be using concepts that were earlier presented in chapter 3 to analyse and discuss the findings. Mainly, the concepts of adaptation, adaptive capacity and adaptive management will be guiding this discussion so that the research questions can be answered.

One of the challenges for long-term adaptive management is to know what to be prepared for, especially when fluctuation of weather extremes can be expected. A majority of the farmers have spoken of adaptive strategies concerning droughts, but little concern was raised against heavy rains and flooding. Although, it was recognized by most farmers that the possibility of both situations exists and that it makes it difficult to plan ahead. But being already used to the dry conditions of the area and after two unusually dry years in a row (although summer 2017 was not very accentuated and did not have the same negative impacts as the following year), most of the interviewed farmers primarily planned and thought about how to adapt their farming to drier conditions. This is mostly noticeable by how alternative drought resistant crops were discussed as an adaptive implementation. This strategy, however, has not solely been a product of feeling a need to adapt to a changing climate, although climate change awareness might be part of the reason. The largest reason to change into more drought resistant crops in the study areas has been because of the naturally dry conditions in Mälardalen. The substitution of crops is the third factor according to Darnhofer, Bellon, Dedieu, & Milestad (2010) which ensures adaptive capacity. An example of substitutions that we have seen in the study is maize and lucerne. Maize substitutes some of the grain used in roughage. Lucerne is a herb which adds some extra protein to the ensilage and is used in ley cultivation. Despite that climate models (SMHI, 2015a; SMHI, 2015b; SMHI, 2015c; SMHI, 2015d) suggest that the heavy rains will be a larger problem in this area, most farmers expect that droughts will become more common in the future and that it will pose a greater threat.

Because the perception of climate change impacts varies between farmers and farms, consequently their choices in adaptive management also differs. An example can be given to illustrate this difference between Farmer D and E. Farmer E had to adapt his production, partly because he expanded his livestock size, but also as a strategy against drought. Farmer D perceives that three harvests per year are not viable and only sees it as an emergency solution. Likewise, Farmer C do not think that climate change will have much impact on agriculture in the nearest 50 years. The different approaches to climate change and what viable actions the farmers can see affect their choices of adaptation, specifically their operational flexibility. But that does not mean that there is no room for adaptation by a farmer that does not believe in significant consequences of climate change. Adaptive strategies are made on daily basis, both long term and short term, but these are not necessarily perceived to be a form of climate change adaptation, or at least not always intentionally. For example, how farmers prepare for crisis or hard times will of course help them to become more resilient in case of extreme weather events (whether it is related to climate change or not). Trying to diversify their livelihoods will also decrease their vulnerability. Arguably, it could be said that the low profit margins in agriculture have made some farms more resilient to shocks and disturbance, as they have been forced to diversify, constantly adapt, make changes and develop their agriculture to improve their liquidity. Some of these adaptive responses could therefore help farmers to become more resilient to climate change.

Johnston & Chiotti (2011) speaks of different obstacles that may prevent farmers from taking adaptive actions, even when they are aware of threats posed by climate change. Irrigation is one of the most prominent examples. Most farmers do not irrigate, simply because it is not economically viable. The economic obstacle works on different levels. Firstly, the biophysical surrounding creates the opportunities and obstacles to make it economically viable. One is the proximity to a water source. Although it is not necessarily so that the farmer needs a lake or stream to irrigate (although it does makes it easier); one can for example build water collection dams or use groundwater. Secondly, there is the issue of small profit margins from agricultural sector that may not make the investment worthwhile. The economic viability of installing irrigation systems would require cultivation of certain crops to make the investments pay-off. Beside the costs, there are also many legislations that are tied to extraction of water for irrigation, whether the water sources come from lakes, streams or groundwater. Additionally, if you would want to change to cash crops, there might exist other restrictions in local agro-climatic conditions (soil qualities, temperature, length growing season and so on) which may not be suitable for some specific crops. It becomes once again a matter of biophysical surrounding. Also, wild boars may pose a problem as they can cause large damages on their preferred crops. At the same time there might exist preferences that makes farmers uninterested in specializing in certain production types only for economic gains. Furthermore, the large investments and specialization of one production type might make it impossible to change to another production type, because the investments may have locked farmers inside one particular production system. This complexity of different factors that affect adaptability could be seen as an example of interaction between systems on different scales as has been suggested by Biggs, Schlüter, & Schoon (2015), where the feedbacks between different components within the system and across systems on different scales affects the adaptability within a farming system. This is also what Gunderson & Holling (2002) calls panarchy.

We have seen several concrete examples of how dynamics nested on different scales affects the agricultural practices, or in this case, the adaptive management. First, we have the ecosystems that of course have an impact on the growth of crops through aspects such as the quality and quantity of soil and quality of water in the fields. Even if there is no water for irrigation available, clean drinking water is still required for animals. A concrete example of the interactive dynamics between different scales can be taken from chapter 5.5.3 where farmer C used moss soils during summer 2018 to cultivate ley. This piece of land has been in his possession for a long time, but never cultivated before because of the soil properties. It required an extreme change in the weather system for this soil to become viable for cultivation. As a result, the farmer cultivated this land and got a high yield in return. Additionally, he made an active decision to acquire more of this land as insurance against future droughts.

Both Darnhofer, Bellon, Dedieu, & Milestad (2010) and Milestead, Dedieu, Darnhofer, & Bellon (2012) writes that long-term strategies and diversification (both on- and off-farm) are important factors for the adaptive capacity. Considering that most farmers must work much more than 40h/week, it makes it difficult to have any other side business or incomes (one exception is Farmer A who does not have agriculture as the main occupation). But most farmers do some entrepreneurial work and confirm that it is a strategy for having a diverse livelihood. This kind of entrepreneurial work is in line with the second factor (Darnhofer, Bellon, Dedieu, & Milestad, 2010) that ensures adaptive capacity, namely the technical systems that determines process and organisation of work. In other words, having equipment (e.g certain tractors) that allows farmers to organise work on their farms, but also having equipment that allows do jobs for others. Another example of this factor can be used from Farm C. First, the farmer has expressed that the lack of milking robots affects the health of the family but changing to a new barn and installing milking robots would reduce some of the heavy work load and change the organisation of work. Looking long-term, if we view the worker as a capital or asset, ensuring his/her health, this would of course be an important consideration. Additionally, changing to a new barn would allow the cows to move freely during grazing season and inside the barn, which means that the farmers do not have to let them in and out on daily basis. This also affect the organisation on work. Overall, these kinds of changes make room for time that can be spent on something else.

A more distinguishable example of diversification would be farmer B who has been working on developing a side business in connection to his farm. A few different drivers behind this strategy was recognized. First is his perception of his meat production. He took pride in his production and emphasized the quality of his meat. It was important for him that this meat would not disappear into a “black hole” as he expressed it. Therefore, he developed different strategies such as opening a shop and working with a wholesaler to promote his production. But it has also an economic reasoning behind it, as selling the meat himself was more profitable to him than selling animals directly to slaughterhouses. There were some issues with marketing strategies and box sizes which of course could improve his income if solutions could be found. The downside is that the whole business is dependent on his agricultural production and is therefore just as vulnerable to a changing climate. Other outside dynamics that also could affect his business is the consumers' preference of eating more vegetarian products. He already mentioned that his total profits from sales have not increased although he has gained more buyers. This was because people eat less meat, he believes. So, it could be argued that his sales have already been affected as he otherwise could have gained more profit from selling meat boxes in his private shop with the increased clientele, if people's preference of vegetarian and non-vegetarian food had been different.

In this study, grain (usually barley) was the one most flexible crop that was used by the farmers, either it is cultivated for commercial purposes or as fodder for their own animals. But during 2018 most of the grain production had to be used for fodder needs instead. Despite that the crops could not be used as a source of economic income, grain provides a flexibility of its usage, which makes it possible to adapt the usage of the crop during a year of crisis. It is an example of how to mobilize components within the farming system in order to be able to adapt (Park, et al., 2012; Biggs, Schlüter, & Schoon, 2015). Another example of flexibility is how to utilize the available acres, which is done by taking active decisions about what crops to cultivate and what size of land to cultivate on. For example, to cultivate grain on a larger area for fodder production, instead of cultivating wheat that is used for commercial purposes. During a bad year, land can be set aside for other cultivation that might be required. Also, a portion of land is sometimes used for experimenting with other crops, such as protein crops or more drought resistant crops such as maize. But at the same time, the farmer is restricted by the available land acreage which may affect his/hers flexibility. For example, a farmer has a certain livestock size and certain land acreage on which the farmer has to produce fodder. The land has to be adapted to his livestock size in order for the farmer to be self-sustained on roughage. The farmer may have more land than it is required, thus leaving him with much larger margins and area that can used more flexible, than the farmer who only has enough land to produce the exact amount of fodder that is needed. We have seen these examples in the case of Farm A and C, which can support a larger amount of livestock than they currently have, which was an important reason why they did not experience fodder shortages despite lower yields. Farmer D also has a larger land acreage than it is required to sustain his livestock, that he uses it for wheat cultivation, but this land can be used for other crops if needed. Additionally, if a farmer would want to expand the livestock size, additional land might be required (such is the case for Farmer B). This would lead to higher investment costs, more inputs in term of diesel, fertilization and so on. Another solution (or a part of the solution), is to maximize the outputs from existing land. This was suggested and done by the Farmer E, who changed from 2,5 harvest/year to 3 harvests/year after his farm expanded in 2006. Thus, the availability of land in relation to livestock sizes is an important component that determines both the adaptive management and adaptability of the farm.

Some of the adaptive management choices that have been made have not always been economically motivated, while other choices have meant not to make any adaptive actions at all. These choices have been based on factors such as personal preferences and long-term health decisions. We can see the example of Farm C where a new barn is going to be built, but the farmer does not want to build for the maximum capacity of the farm, because he preferes for a specific livestock size. Of course, the economical aspect has been almost always taken into the account because the survival of the farm needs to be ensured, but as Darnhofer, Bellon, Dedieu, & Milestad stated (2010) writes, all choices made by farmers are not based on maximization of profit. Continuing with the example from Farm C, where the farmer needs to expand and renovate his barn because the work load is taking its toll on the health of the family members working on the farm. The bank wants him to expand for more than he wants to, but at the same time it is necessary for him to ensure the health of the farm members. Yet, he still cannot come to an agreement with the bank.

Self-sustainability on farm level makes the farm more resilient to outside disturbances when it becomes less dependent on components that require access and availability. In case of crisis, being able to produce the required inputs makes the farm less vulnerable than those farms who rely on inputs from outside. It is of course not possible for a farm today to be completely self-sustainable. The largest issue as of now is the dependency on fuel. The organisation of farms (their machines) requires fuel for the farm to be fully functional and it is not until we have the necessary technological solutions and political instruments that farmers can become less dependent on fuel. There are of course factors that will always make farms vulnerable, even when they have a high degree of self-sustainability (or as much as it is possible). Large scale dynamics such as climate change, markets and political decisions will always have a consequence on farm's resilience. During the interviews, we have discussed how to become more self-sustained on farm level. Beside the fuel, access to fodder was raised as the second most important factor. All roughage in this study is produced on the farm level and in that sense all farms are self-sustained. But protein fodder is equally important. Most of the farmers have a very small protein production or have tried it in the past. Some obstacles to produce own protein fodder exists because of economic consideration. For example, Farmer A has considered to grow some peas to have more variation in the crop rotation, but she has not done so because the costs for production needs to be calculated. She does not have the required equipment to create protein fodder, so new investments would also be required. Farmer C finds it more convenient to buy protein fodder from other local producers because it is much simpler for him than produce it himself and he also wants to support other local producers by buying their products. Both Farmer A and C sell grain or wheat, which covers the costs for fodder supplement. As of now, it is an easier solution for them. In case of Farmer B, his largest obstacle are the wild boars in the area which have destroyed his pea plantations in the past. However, in case of a prolonged growing seasons in the future and the possibility of having three full harvests a year, some of the farmers see an opportunity of growing own protein crops in-between spring and autumn sowing.

7 Conclusions

In this chapter I will conclude my main findings that were discussed in the previous chapter. I will finally conclude this paper by presenting some of the study limitations, its relevance and how it could have been conducted differently.

7.1 Main findings

The main conclusions that can be drawn from the findings and the discussion to answer my research questions are following;

The opportunities and challenges of climate change are perceived differently between the farmers. Some farmers do not perceive global warming as a threat, some think that changes of weather, such as drought in 2018, are normal. Others see weather extremes as a large threat and have a difficulty of knowing how to prepare for it because weather extremes tend to fluctuate between wet and dry conditions. Farmers from this study are mostly prepared for dry conditions and are taking adaptive measurements accordingly. This is partially a result of local agro-climatic conditions. Some farmers see opportunities of a warmer climate; it might allow cultivations of new species, more specifically some protein crops that can be used as fodder. Another opportunity which is perceived, is the ability to grow three full harvest.

The adaptative strategies that have been undertaken to prepare for climate change are mostly done by using drought resistant species such as maize and lucerne. The farmers prepare themselves mainly for drought as they think it will be the largest consequences of climate change. None has expressed that they prepare for fluctuations in weather extremes, partially because they do not think flooding and heavy rains will be much of a problem or that they do not know how to prepare for both. Beside using drought resistant crops, other strategies of adaptation are installation of irrigation system, purchases of more land, use of different sources of income and short-term decisions of how to mobilize and utilize physical farm assets such as crops and land.

The obstacles for climate change adaptation that has been mentioned by farmers is the financial ability to invest, some biophysical limitations (such as access to water), not knowing what to prepare for (wet or dry weather extremes). Conditions that create an opportunity for adaptation are often becoming the obstacles when these conditions are lacking; such as financial ability to invest, some favourable biophysical conditions and degree of flexibility on farm level.

Finally, the mental models of farmers from this study vary greatly. They have some similarities but also many differences. This affects how and if they chose to take certain adaptive measurements because prioritise sometimes vary. Additionally, the contexts of every farm have been very different and showcases how adaptability is very place- and context specific, although there are dynamics on different scales that have similar impacts on each farm. Thus, there is no one size fits all solution to adaptive management on farm level.

7.2 Study limitations and further research

In this study, the theory of socio-ecological systems (and how it can be applied to farming systems) has been used to guide the research. The theories and concepts were chosen prior to the field study and therefore some critics might say that the findings were fit into a box and that other concepts or theories could have been more suitable for the analysis. I recognize these limitations, however, duo to time limit of this study, it was necessary to delimit myself to some theoretical framework before beginning the study. There is also the critique of applying system-thinking to social phenomena. At the same time, the social phenomena cannot be applied to the biophysical nature. Hence, the relevance of SES is such that it attempts to combine both worlds into one analytical framework as both human and natural aspects are in constant interaction with each other. This was also another limitation of this study, that I was not able to go too deep into that biophysical aspect of every individual farm in this study. Then time limitation was also the reason why I did not go into the whole concept of resilience and adaptive cycle but focused mainly on the adaptation. Otherwise, it would have required a different methodological approach and a much more complex analysis.

The aim of this study was to use farmers' perspective; hence I did not go much into the institutional aspect of adaptive management. Institutions play an important role in adaptive management even on individual farm level. Some critique can therefore be aimed at not highlighting the institutional role in this research. However, I believe that it would have resulted in a completely different study if I had used an institutional approach. Hence, there is room for more research on the interaction between farmers and institutions and what impact it has on climate change adaptation on farm level.

Furthermore, a larger sample of farmers could have been used in this study. Due to certain restrictions that were mentioned earlier and time constraint, it was unfortunately not possible to interview more farmers. However, this study's aim was never to make a general conclusion. On the contrary, it has showcased the complexity of different factors and how they can affect climate change adaptation. I hope that this paper will bring some insights in the challenges with climate change adaptation that may arise on individual farm level and especially that the importance of farmers' decision-making and mental models are recognized.

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Appendix 1

Description of interviews

Representatives from organisations and governmental agencies

Official from county administration in Södermanland, *Greppa-Näring*
Official from county administration in Stockholms Län, *Greppa Näring*
Representative from farmers' organisation Ekologiska Lantbrukare
Representative from The Federation of Swedish Farmers

Detailed description of farms

Farm A

This farm is located outside of Enköping just north of Mälaren. The owner of this farm is leasing the land from her father and uncle that owns the farm (a total of 200 hectares farmland and 180 hectares forest). The land she is leasing is 60 hectares farm land and 20 hectares grazing land. The grazing area includes some forestry which is both deciduous and coniferous forest. On the cultivated land consists of 70% green fodder and 30% cereals. Cereal production is both used as fodder and for commercial purposes. The main production of the farm is meat production. The farm has a hard of 22 female cows which give birth to calves which are then sold directly to the butchery or as steers to other farms.

The owner acquired her lease in 2017. She originally intended to increase her to 40 cows, but because both year 2017 and 2018 were very dry years, she has not yet done so. The farm produces all the roughage that is required to feed the animals, as well as having grazing land for the animals. For young calves that are used for meat production, she has to buy high protein supplements to ensure a fast and early growth. The calves are sold between February and April and the cereals are sold during autumn. The steers are also sold later in autumn.

Farm B

Although being a family farm, the owner of this farm in Vallentuna, did not inherit the farm from any family member, but was ever since young age interested in agriculture and wanted to become a farmer. He began to lease farm land together with his wife in 1995/1996, but eventually they could purchase the land in 2005/2006 as it had to undergo a renovation process which was considered too expensive for the previous owners. In the beginning, the farm had around 30-40 cows for meat production and about 2000 laying hens. Today the farm has about 35 suckling cows which each gives one calf a year. Additionally, bull calves are bought from other farms nearby. As most, the farm may have up to 150 livestock in one year. A few years earlier, the farm expanded their egg production when they doubled their amount of laying hens. The farm has 150 hectares land which is used for cultivation, including ley production and grain production. Some of the grains is sold to improve the farm's liquidity. Farmer expressed that they have a traditional, Swedish production with traditional crop cultivation.

Farm C

Approximately 45km northeast from Uppsala lies a milk farm, which has around 60 cows and 350 hectares of farm land. Additional 55 hectares of forest land in proximity belongs to the farmer. 1/3 of the land is used for ley production and remaining 2/3 for grain production. Some of the grain is sold, but the remaining grain is used as fodder for their cows. They also press own hay for sale. The farm does not have a milking robot and all milking is done with a milking machine (they have 7 in total). There are currently two-three people (all family members) working on the farm. The plan is to expand the farm to 140 cows buy two milking robot. This has not happened yet, as there are some agreement difficulties between the farm and the bank.

Farm D

The farm is located east of Enköping and close to Mälaren. The main production of this farm is milk production. The herd consist of 150 milk cows and about 200 young calves which are used for meat production and recruitment. The total area of cultivated land is 180 hectares of which 90 hectares is leased land. 120 hectares is used for green fodder cultivation and the remaining land is to grow different crops such as maize, barley and wheat. All crops are used for producing animal fodder and is enough to cover the animal feed requirements with the exception of protein supplements which has to be purchased.

Farm E

Another farm located in Vallentuna, which is approximately 45km north of Stockholm and 40km southeast of Uppsala. This farm specializes in milk production and crop cultivation. It has 110 milk cows, 460 hectares of crop cultivation and 300ha forest. The largest cultivated crop is wheat which is mainly used for commercial purpose. Approximately 150-200 hectares is used for cultivating wheat, but sometimes also for other crops such as oilseed crops. Remaining land is used for green fodder production and other crops that are used as roughage (of which 25-30% is maize). The farm is self-sustainable on animal feed, except for protein supplement.