Master thesis – master Sustainable Development

SHAPING CLIMATE CHANGE ADAPTATION: THE IMPACT OF FARMERS' PERCEPTIONS

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SUMMARY

Climate change is affecting different areas of life. Especially agriculture is hit hard, since this field is highly dependent on weather and climatic conditions. To adapt to the outcomes of climate change, farmers engage in climate change adaptation measures. Perceptions of climate change are hypothesized to affect climate change adaptation. The exact impact is unknown. At the same time, farm characteristics, such as farm management style and farm size are expected to influence perceptions. Therefore, the main research question in this study is: How do farmers' perceptions of climate change influence farmer's adoption of adaptation practices? Subquestions regard the characterization of the perceptions and the role farm and farmer characteristics play. The second sub-question goes into how farmers adopt to climate change and what measures they use. The third sub-question regards the link between perceptions and climate change adaptation. To gain an answer to this question, farmers were interviewed. The Schorfheide-Chorin biosphere reserve is an area in Germany with a high organic farming percentage, where the outcomes of climate change are largely negatively experienced. In this research, 13 interviews were conducted with farmers about their perceptions of climate change and climate change adaptation measures. 2 Experts were interviewed about climate change adaptation and what tools are available for farmers to adapt. It was found that while farm characteristics do not have a strong significant impact, perceptions of climate change among farmers varied with a few central themes, such as droughts and heavy rain. Most farmers have a broad perception of climate change and perceive many different outcomes. In response to this, farmers are adapting to the changing climate, with each farmer having adopted many different techniques. The most used techniques followed almost the same order as the most mentioned perceived outcomes of climate change. However, some challenges still stand in farmers' way when wanting to adopt climate change adaptation strategies. This is mostly a disconnect between farmers and policy-makers, causing farmers to distrust some government institutions. A lack of subsidies causes economic troubles for farmers. However, despite the challenges, farmers prove themselves to be willing and able to adapt to climate change. Lastly, perceptions of climate change do influence climate change adaptation behaviour. Farmers that have the least complex perceptions, also tend to adopt the least adaptation techniques, while farmers with a more complex perception tend to adopt more techniques. This result was also found in studies done in other parts of the world, however, researchers are calling for more research to be performed on this subject. To narrow the gap between farmers and government, a more personal method of policy-making should be applied that is more tuned to the farmers' unique conditions.

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1. INTRODUCTION

1.1 PROBLEM STATEMENT

Farmers are experiencing increased environmental problems caused by climate change. While climate change issues in agriculture will affect all humans in the long run, food producers are the first to encounter the shocks of a more unstable climate (Soubry et al., 2020). However, to adapt to a changing environment, a certain level of awareness of the challenges is needed. Each producer has a different mindset and perception of a changing climate and environment, and may therefore react differently to these challenges. Their perceptions inform what farmers choose to do with their agricultural land, as well as the measures they take to adapt to a changing environment and minimise their part in the environmental problems caused by agriculture (Fierros-González & López-Feldman, 2021).

Around the world, farmers are vulnerable to experiencing negative changes due to climate change. These include a great increase in drought as well as hot spells, and differential rain. This affects the types of crops farmers are able to plant, and the profit they gain from their farm (Macholdt & Honermeier, 2016). With the increase in extreme weather events, the livelihood of farmers could become more high-risk and uncertain (Soubry et al., 2020). Biodiversity is also affected, among other things, by climate change. In agriculture, this is exacerbated by soil life not adapting to higher temperatures. An added factor that contributes to biodiversity loss is the usage of pesticides by farmers. Pesticides have detrimental effects on the natural environment (Sattler & Nagel, 2010). Climate change can also cause soils to degrade and therefore, to increase the productivity of their land, farmers have had to use more pesticides and fertiliser, which in turn, can lead to a decrease in biodiversity (Turck et al., 2022).

Despite all these challenges being faced by farmers, they are not helpless. Farmers all around the world have been forced to act on the diverse problems they face (Soubry et al., 2020). The adoption of adaptation practices is important to decrease the risk that climate change poses to agriculture (Turck et al., 2022; Osterburg, 1999, Sattler & Nagel, 2010). There are different adaptation practices to be employed by land-users, for example, organic farming, reduced tillage, or crop rotations (Turck et al., 2022). Organic farming can result in more carbon being stored in the soil and bring about a stronger resilience to extreme weather events (Scialabba & Müller-Lindenlauf, 2010). However, there are also factors holding farmers' adaptation back. These can include farm and farmer characteristics, such as educational background, socio-economic factors, or political factors (Mittler et al., 2019; Rust et al., 2021).

1.2 RESEARCH GAP

Some components of this research have been studied at present. Multiple studies focus on the impact of climate change on farmers (Li et al., 2017; Soubry et al., 2020; Fierros-González & López-Feldman, 2021). Moreover, the concept of perceptions has also been in the focus of scientific research. There has been research focusing on farmers' perceptions of ecosystem services for example (Smith & Sullivan, 2014; Teixeira et al., 2018). Other articles focus on different aspects of perceptions, like the role of self-identity (Hyland et al., 2015), and different types of perceptions (Hyland et al., 2015). There is literature on socio-economic factors that influence the adoption of adaptation practices, but the connection to perceptions is still largely not made. It is hypothesized that farmers who have experience with extreme weather events related to climate change have a higher risk perception of climate change and are therefore more likely to adopt adaptation measures in the future (Li et al., 2017). This study gives an example of how experience and perceptions can be related to adaptation practices. However, this research uses a different idea of perception, and focuses more on awareness and social, economic and natural capital. Li et al. (2017) also argue that the connection between climate change adaptation and perceptions has not been studied enough.

Moreover, in perceptions research, there is a tendency for more quantitative and historical research based on the perceptions of groups, instead of putting perceptions in the context of the individual (Soubry et al., 2020). The research by Hyland et al. (2015) and Teixeira et al. (2018) showed that farmers have very different and contrasting perceptions and that this close individualist perspective also deserves scientific attention. In literature about climate change adaptation, it is also pointed out that more attention should be paid to farmers' individual perceptions. Much of the research now is focused on farm variables such as farm size or farmer income, which are not perceptions, but are expected to influence them (Propoky et al., 2019).

At the same time, much of the literature on climate change adaptation has a focus on the Global South, focusing mostly on climate change adaptation in Latin America, Africa, and Southeast Asia (Fierros-González & López-Feldman, 2021). While there is some literature on Germany or Europe as a whole, there remains to be a lack of research on this part of the world (Fierros-González & López-Feldman, 2021). Moreover, there is no scientific article about the climate change perceptions or climate change adaptation of farmers in the biosphere reserve Schorfheide-Chorin, in the northeast of Germany, where this research was conducted. There are some articles about natural protection, but none specific on agriculture or climate change. The state of Brandenburg faces a scarcity of precipitation and experiences climate change effects more than the others, which makes studying the impacts of climate change and the reaction of farmers important (Lippert, 2009). The reserve is important for nature, since it creates an important hotspot for biodiversity (Pflanzen Und Tiere - Natur & Landschaft - Biosphärenreservat Schorfheide-Chorin, n.d.).

1.3 RESEARCH QUESTIONS

This research aims to better understand what drives perceptions of farmers on climate change, and how their perceptions may influence the adoption of adaptation practices. Therefore, the main research question is: How do farmer's perceptions of climate change influence farmer's adoption of adaptation practices?

To answer this main research question, sub-questions have to be addressed. First, the farmers' perceptions have to be understood and categorised. Therefore, the first question to be answered is: what characterises farmer's perceptions of climate change how do farm(er) characteristics influence them? From this question, it can be seen which perceptions exist among farmers, and how they contrast and differ from each other. Here, the characteristics that influence farmers' perceptions are also examined. The second question is: How do farmers adapt to the challenges faced by climate change? Climate change adaptation is a reaction to the challenges experienced by farmers from climate change. The last question links the perceptions with adaptation practices. How are farmer's perceptions of climate change linked with adaptation practices? All questions are summarised in Table 1.

Table 1: Summary of the main research question and three sub-questions, with the main research question being: How do farmers' perceptions of climate change influence farmer's adoption of adaptation practices? The first sub-question goes into perceptions, the second into adaptation practices, and the third goes into the link between those.

	Research questions
Main Research question	How do farmers' perceptions of climate change influence farmer's adoption of adaptation practices?
Sub-question 1	What characterizes farmers' perceptions of climate change and how do farm(er) characteristics influence them?
Sub-question 2	How do farmers adapt to the challenges faced by climate change?
Sub-question 3	How are farmers' perceptions of climate change linked with adaptation practices?

The answers to the sub-questions will aid in answering the final research question.

1.4 RELEVANCE

Since the public becomes increasingly more aware of environmental problems in part caused by agriculture, the push from consumers for more sustainably farmed food becomes larger to alleviate these environmental problems. Farmers are reacting to this call by adopting conservation measures to alleviate both problems caused by farming, but also to adapt to the changing environment (Turck et al., 2022. Hobbs et al., 2007). Since the adoption of adaptation practices, like organic farming, is hypothetically influenced by farmers' perceptions, researching this link will aid in solving the question of what underlies farmers' decisions to adopt adaptation practices. With the results of this study, policy-makers and governmental figures can act on the knowledge gained and for example, facilitate farmers' decisions to adopt conservation techniques, such as climate change adaptation. Furthermore, if more conservation measures are adopted, the environment will benefit which in turn, benefits all humans (Turck et al., 2022; Ostenburg, 1999). Therefore, this research also bears societal relevance.

Next to societal relevance, this research also holds scientific merit. Farmer's perceptions and especially the role of those in the adoption of adaptation practices continue to suffer from a lack of reliable studies. Therefore, this research has a role in closing the gap in literature, since it contributes to both research on perceptions of farmers as well as adoption of adaptation practices, especially in a geographical location with lacking research. It also is relevant for sustainable development, since goal 12 of the Sustainable

Development Goals is to ensure sustainable consumption and production (UN, 2015). To do that, food production should be environmentally, as well as socially sustainable. The increased usage of adaptation practices by farmers could make the food chain more sustainable.

This thesis is divided into 5 different sections. First, the theory and concepts in which this thesis is embedded are explored. Then, the methodology followed to come to the data needed for the results is explained in detail. The results section follows in which the results found in this study are presented, starting with the results on climate change perceptions of farmers, then the results on climate change adaptation, and lastly the link between the two. In the discussion part after this, the results are discussed and put into a wider context. The research ends with a conclusion.

2. CONCEPTS AND THEORIES

In this section, it is explored where in the existing theories and literary concepts this research fits. The background of all theories and concepts is looked at and this research is placed in a body of literature. Moreover, the concepts that are central to this research are explained and an overview of the concepts background in literature is given.

2.1 CONCEPTUAL FRAMEWORK

The central concepts are: farm and farmer characteristics, perceptions of climate change, and climate change adaptation. These are the variables central to each of the sub-questions and the main question in the study. The perceptions and characteristics are the subject of the first sub-question, climate change adaptation of the second, while together the concepts are central in the third sub-question as well as the main research question. These main concepts are made up of different sub-concepts as well, that have an explanatory role in the understanding of the main concepts, these sub-concepts are explored in the coming sections. In Figure 1, the conceptual framework is portrayed. 1,2 and 3, refer to the number of the sub-question belonging to the connecting arrow or concept.

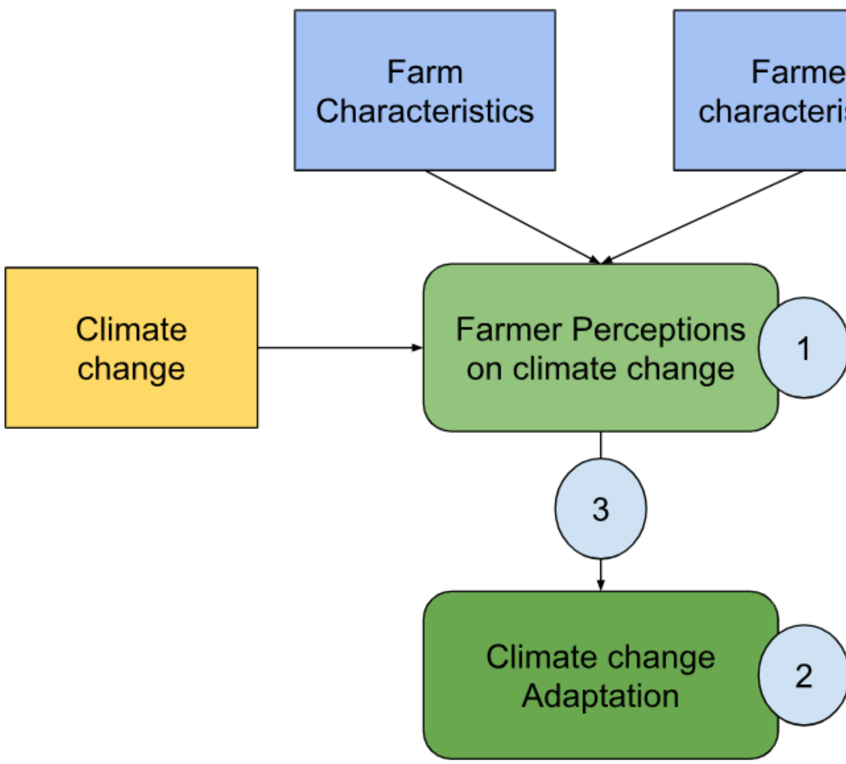


Figure 1: Conceptual framework with central variables of farmer perceptions and climate change adaptation. Climate change, farm characteristics and farmer characteristics influence farmer perceptions. Subquestions 1,2 and 3 are regarding the nature of the perceptions, of climate change adaptation and the link between them

First, the concepts have to be defined. This will be done mostly by literature study. Then, the wide array of differences in farmers' views of the concepts will be discovered in the field research. To analyse these differences, the concepts must be operationalized. The operationalization will be carried out by utilizing different methodologies, which will be expanded upon in the methodology section.

In the literature, the concepts are still mostly stand-alone, and there is no theory on how these three concepts link together in the specific setting of agriculture. Therefore, in this research, a theory will be developed on how the concepts are interlinked and what causal connections exist between the concepts, based on different types of methodologies.

2.2 CLIMATE CHANGE IN AGRICULTURE

A central part of this research is climate change. Climate change is a reality, and its effects will cause real adverse impacts on people and ecosystems worldwide. A sector heavily impacted by this is the agricultural sector, because of its reliance on weather. Outputs and the people relying on those are increasingly vulnerable (Kurukulasuriya & Rosenthal, 2013; Lippert, 2009). Climate change is presenting farmers with conditions they have never experienced before. The impact of climate change on agriculture, especially in the future is still largely uncertain. Climate change affects many different aspects of agriculture, for example, yields, herd management, and input prices (Troost & Berger, 2014). To cope with the increasing dangers of climate change, farmers have adopted strategies, or climate change adaptation measures (Kurukulasuriya & Rosenthal, 2013).

While there are many adaptation practices in all fields, in this research, only those in agriculture are discussed. In adaptation practices in agriculture, it is important to adapt the farm to a more unreliable climate. Adaptation to climate change is different per country or region, since climate, as well as political and socio-economic conditions, are different everywhere. In Germany, it is especially common to reduce the amount of inputs and rotate crops (Sattler & Nagel, 2010). Underlying the adoption of adaptation practices, there are different theories to be found in the literature. Some scholars call for the connection with perceptions to be made (Prokopy et al., 2019). Common in research is for farm characteristics to be tied to the choice of conservation agriculture (Propoky et al., 2019), and socioeconomic factors (Sattler & Nagel, 2010; Turck et al. 2022). However, to adapt to the climate, farmers need to perceive the change in the climate first before being able to act on it (Li et al., 2017). In this research, these underlying mechanisms of climate change adaptation are explored, especially the perceptions and farm(er) characteristics.

2.3 FARM(ER) CHARACTERISTICS

In this section, the characteristics underlying the perceptions are discussed. Characteristics in this study refers to characteristics of farmers and farms. These are specific to each farm and farmer and include personal characteristics and characteristics specific to the farmer’s farm. Part of the farmer characteristics are socio-economic characteristics, such as income. There is literature about the role of socio-economic characteristics in climate change adaptation among farmers. (Prager & Posthumus, 2010; Adesope et al., 2012). Rogers 1995 stated that farmers make decisions in order to optimize productivity and minimize the cost of inputs into farming. However, Adesope et al. (2012) argue that characteristics such as access to markets and having credit also contribute to the adoption of climate change practices such as organic farming.

Some characteristics mentioned in the literature are age, education, financial background, farm size and gender (Li et al., 2017; Dang et al., 2019; Prager and Posthumus, 2010). Results about the impact of characteristics like education level or gender are mixed, with some studies not finding significant influence on adaptation, and others finding correlation or causality. For instance, Li et al. (2017) found no significance when it comes to education level. On the other hand, Propoky et al. (2019) found education level to be relevant. Prager & Posthumus (2010) also found financial incentives, like subsidies to be a factor in farmer's decision to adopt adaptation practices, but this did not affect their perception. Another relevant aspect of climate change adaptation is future perspectives, and how long the farmer is intending to run the farm for. Therefore, Urdiales et al. (2015) argue that younger farmers are more eco-focused, as well as farmers who have greater future perspectives. Li et al. (2017) found gender and age to be significant, but they could not find conclusive results on whether farm size plays a role. The mixed results from the literature show that the significance of these farm(er) characteristics is very dependent on different factors such as the geographical location where the study was conducted. Since my research was carried out in a place vulnerable to climate change, this characteristic will be similar for all participants in the study.

2.4 FARMER PERCEPTIONS OF CLIMATE CHANGE

The second concept discussed is perception. This concept is the most central and broad subject of the research. It is used in all three sub-questions and the main question. Perceptions relate to individual beliefs and views on certain aspects, in this case, climate change (Smith & Sullivan, 2014). Perceptions relate to how we as people experience and interpret reality and how we determine action and behaviour. Knowledge and perceptions are very strongly intertwined, they are not the same, however. Perception is based on knowledge as well as belief. In climate change specifically, perceptions are about an individual's relationship with climate change (Soubry et al., 2020). Investigating farmer perceptions and relating them to agricultural practices has been going on for years (Smith & Sullivan, 2014). Through these years of research, it has been found that individual perceptions are highly important in decision-making. Individual perceptions have been discovered to form the ground for action (Li et al., 2017).

There are several theories about behavioural changes and most start with the individual and their perception, making perceptions crucial in the decision-making of individuals (Li et al., 2017). Since individuals all have their own unique set of characteristics for their perceptions, each perception is different. However, there are groupings to be made in perceptions, for example, how high or low farmers perceive the risk of climate change (Hyland et al., 2015). Since every farmer differently perceives environmental problems, they also all have different ways to act (Fierros-González & López-Feldman, 2021). In climate change adaptation in agriculture, several studies have found different ways to determine farmers' perceptions. While Li et al. (2017) focus on awareness of extreme weather events as the ground for perceptions, Soubry et al. (2020) tie perceptions more to the perceived risk of climate change. They therefore also define perceptions on judgements of risks posed by climate change, and the reactions to that risk.

In order to answer sub-question 1: what characterizes farmer's perceptions of climate change, a literature review was conducted before the interviews were performed. Doing this literature study gives the researcher a better view of what is actively affecting farmers when it comes to climate change. The interviews deepen this knowledge and make it location- and individual-specific. For the same purpose, a literature review on adaptation measures was performed. When asked for adaptation measures, some farmers might not know they are using adaptation measures, therefore measures were studied beforehand.

In the literature, multiple environmental problems related to climate change faced by farmers were found, many of those specific to Germany. Since these studies are largely based on interviews, many of these impacts and effects are the perceived effects of climate change. While there is quantitative data, like temperature changes, those are not used in this research, since they leave out the people-centred perspective. In this research, only the temperature changes that are observed by farmers are considered. In the literature, the main effects of climate change experienced by farmers are: increasing temperatures, increased risk for pests and diseases, seasonal changes in precipitation (Macholdt & Honermeier, 2016), heat stress in animals (Para et al., 2018), drought stress (Riediger et al., 2014), the ability to grow new types of crops (Gournall et al., 2010), heavy rain storms and soil erosion (Routscheck et al., 2014) and differences in growing season (Menzel et al., 2006). This knowledge was later used in the interviews to prompt participants.

2.5 CLIMATE CHANGE ADAPTATION

The IPCC defines climate change adaptation as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). However, there is still discussion on how climate change adaptation can be best implemented and researched. Many publications do call for the involvement of stakeholders (Reyer et al., 2011). In this research, the stakeholders are the farmers.

Research has been done to identify climate adaptation practices among farmers in Germany. While this research is oftentimes very specific and focused on one region, it is important to add to the body of research in this area. Since the effects of climate change can be perceived as regional, so does the response to climate change. In the study done by Eggers et al. (2014), it was found that the degree of climate change adaptation done by farmers was largely affected by geographical factors, such as the amount of rain. Therefore, they found differences in the responses of their participants depending on the region.

Methods of climate change adaptation applied by farmers in Germany found in the literature are: Crop variety diversification, irrigation, changing planting and harvesting dates, planting trees within the crops or in pastures, and applying methods of soil conservation (Dang et al., 2019). Eggers et al. (2014) found the introduction of new crops and the adaptation of tillage also to be introduced often.

Another measure often seen in farms is the rejection of agro-chemicals, and the application of soil conservation measures (Osterburg, 1999). A study done by Reyer et al. (2011) in Brandenburg, uncovered more climate change adaptation techniques more adapted to the region. They emphasize farmers' needs to improve water infiltration, decrease evaporation in the soil, prevent soil erosion and improve soil structure.

2.5 SUITABILITY

The concepts are all gathered from literature and from the European Union project this thesis is part of. The project is called: Europe-land: Towards Sustainable Land-use Strategies in the Context of Climate Change and Biodiversity Challenges in Europe (IAMO, n.d.). Since the project itself is too big for the thesis, in this research, the specific point of farmers' perceptions and their influence on the adoption of adaptation practices is measured. Therefore, the concepts of perceptions and adaptation practices are appropriate and contribute to a real-life project as well as a literature gap. Since perceptions are broad, the characteristics are also considered as they are found to influence perceptions as well as adaptation practices. Adaptation practices also give a holistic picture of all measures taken by farmers to combat climate change issues on their farms.

2.6 HYPOTHESIS

Based on the literature, the hypothesis for this research is as follows: when farmers have a complex perception of climate change, i.e. they perceive many risks of climate change on their livelihood and their farm and they view climate change as more negative, they are more likely to adopt adaptation measures. While if farmers have a less complex perception, they are less likely to adopt climate change adaptation practices. While characteristics might be the foundation of perceptions, there are also other factors influencing adaptation, such as economic factors, (Turck et al., 2022). Perceptions are expected to play a significant part in the land-use decisions of farmers and have a significant impact on climate change adaptation. In the next section, it is explained how to measure the influence of perceptions of farmers on the adoption of adaptation practices.

3. METHODOLOGY

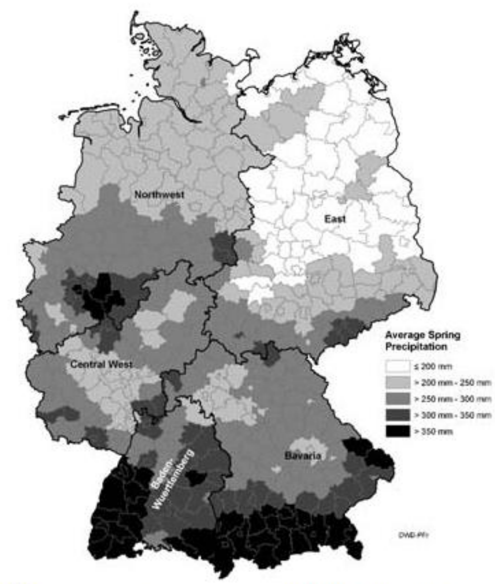
In this section, the methodology of the thesis is explained. Since this research has a wide range and the sub-questions required to answer before being able to answer the main question, multiple methods have been used.

3.1 STUDY SITE

This research was conducted in Germany. Germany plays a big role in the transition to more sustainably sourced food, since it is the biggest organic market in the EU. Moreover, the adoption of conservation measures, such as climate change adaptation techniques, among farmers is on the rise. On the other hand, some farmers are holding on to a traditional way of farming, and a countermovement of conventional farming is also strong. The vast array of differences in farming methods in Germany, and the rising social pressure for more nature-inclusive farming, make it a good country to do research and find out what influences the adoption of adaptation practices (Fibl, 2023). Much of the German fertile land is used for agriculture and the sector remains of importance (Alt et al., 2011). Germany also hosts a wide range of soil types, such as sandy soils, loam and clay soils. The type of soil is important for climate change adaptation and fertility (Encyclopedia Britannica, n.d.).

Figure 2: Map of the study site. The research took place in the Northeast of Germany, in the green part in the map (source: https://de.m.wikipedia.org/wiki/Datei:Karte_Biosph%C3%A4renreservat_Schorfheide-Chorin.png)

In the Europe-land project, a case study was conducted in the Northeast of Germany in the state of Brandenburg, in the Schorfheide-Chorin biosphere reserve (Figure 2). This biosphere reserve is not a completely naturally protected one, so farmers are still allowed to farm there. However, since the area is under natural protection, many farmers in this area farm organically (IAMO, n.d.). Moreover, the state of Brandenburg has some of the fewest rain and sandy soils, as can be seen in Figure 3 (Macholdt & Honermeier, 2016). This situation will be even further exacerbated by climate change with precipitation in summer continuing to fall further in the east of Germany. Together with this, evaporation increases as well because of the rising temperatures in the area (Lippert, 2009)



(a) Reference: Average spring precipitation (1961-1990).

Figure 3: Precipitation Germany. The lighter parts represent less precipitation, while the darker parts receive more precipitation (Lippert, 2009)

The fieldwork was conducted in and around this biosphere reserve to contribute to the research of IAMO and the overall EU-project. Since there is a limited number of farmers in the reserve, farmers around the reserve were also chosen for interviews. The combination of sandy soils and decreasing precipitation in the reserve makes this an interesting place to study the impact of climate change, as well as the different land uses in the area. This can be seen in Figure 4, where the yellow parts represent agricultural land, the light green meadows, and the dark green forest. As can be seen in the figure, there are many lakes, but not many built-up parts. Moreover, the high number of organic farmers makes it possible to do a comparison between organic and non-organic farmers.

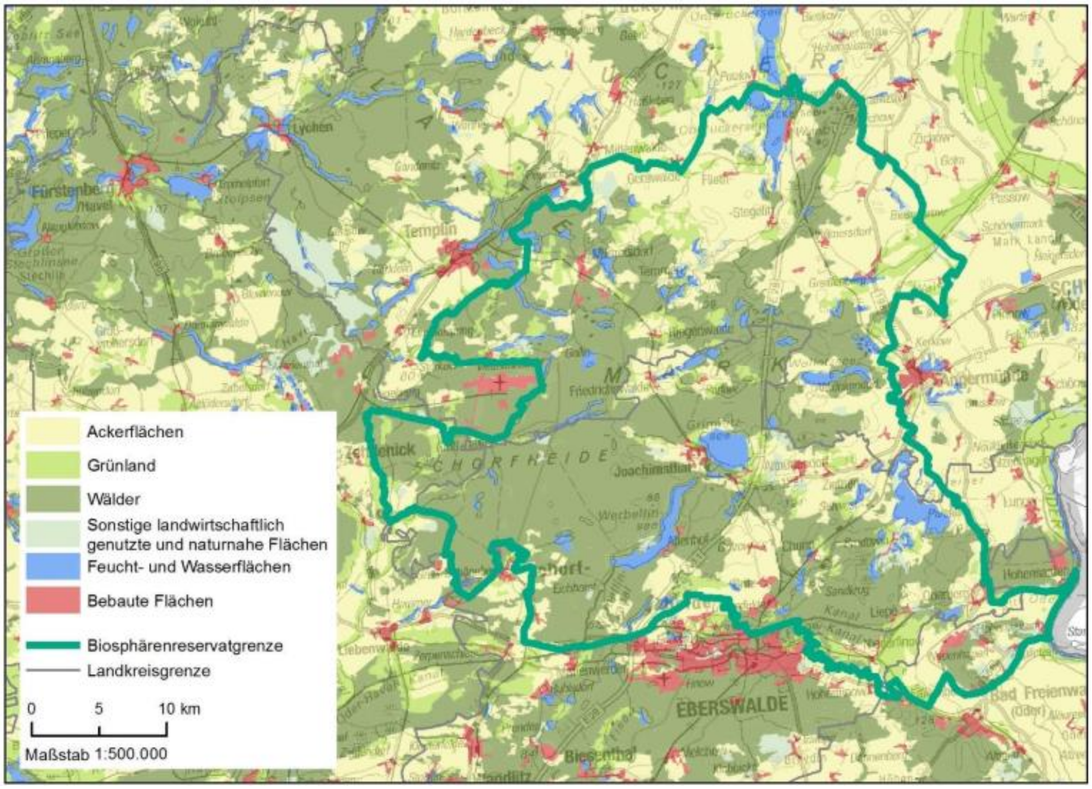


Figure 4: The land-use in the Reserve. Dark green represents the forests in the reserve, and forestry activities. Light green is grassland and pastures. The yellow parts are the land used for agriculture as arable land. (source: https://www.ifls.de/fileadmin/user_upload/II.6_NNL_EE_BR_Schorfheide-Chorin_2018-02-01.pdf)

3.2 SELECTION OF FARMERS

This research included both arable farmers and mixed farmers. Arable farmers are also greatly impacted by a changing climate and a degrading environment. At the same time, arable farmers are the ones who have great potential to adopt conservation measures (Gütschow et al., 2021). However, also livestock farmers can experience different effects from climate change, and have the potential to adapt to a changing climate in a different way from arable farmers (Gütschow et al., 2021), therefore this research also includes mixed farmers. This gives this research a holistic picture of the situation of all farmers in the region.

These farmers were contacted with the help of the IAMO and other contacts of the researchers involved. A formal letter was sent to farmer associations in the name of the main researcher from the overall project of the institute, calling for participants. From there, snowball sampling was used to gain extra participants. This was done mostly through one of the contacts of the main researchers of the project, who had many contacts willing to do an interview with us. Moreover, farms were found online and contacted as well. To gain a broad spectrum of perceptions, an active effort was made to ensure all types of farmers were included. Therefore, multiple farmer associations were contacted. This included the regional farmer associations which represent the conventional farmers, as well as organic farmer associations.

3.3 RESEARCH FRAMEWORK

This research is performed over multiple stages. This is shown in Figure 5 below. Stage 1 consists of desk research for sub-questions 1&2. For sub-question 1, this entails a detailed list of all climate change effects farmers from Germany experience according to the literature. For sub-question 2, this was a literature research on how farmers respond to climate change in Germany. This literature research was done to gain background information about climate change in Germany, and to be more informed during the interviews, to have an idea of what farmers are referring to.

Stage 2 started with identifying farm and farmer characteristics. This happened at the beginning of the interviews, by asking farmers questions about the size of their farms, and whether they were organic or not.

Stage 3 consists of the exploration of sub-question 1 in practice. Farmers' perceptions were characterized by doing interviews with farmers in the reserve. During these interviews, fuzzy cognitive maps of their perceptions were constructed. These fuzzy cognitive maps were later analysed.

Stage 4 was about exploring sub-question 2. In this stage, farmer strategies to adapt to climate change were explored. The interviews were used for this as well. In this part, farmers were asked how they respond to the phenomena caused by climate change that they mentioned earlier in the interview. Here, a list of adaptation practices was created.

Stage 5 goes into the analysis of the results gathered in the interviews. This analysis includes the statistical regressions based on the data gathered in the interviews. This regression will test the significance of the causal relationship between perceptions and the number of climate change adaptation measures, in which perceptions are hypothesized to have an impact on adaptation measures.

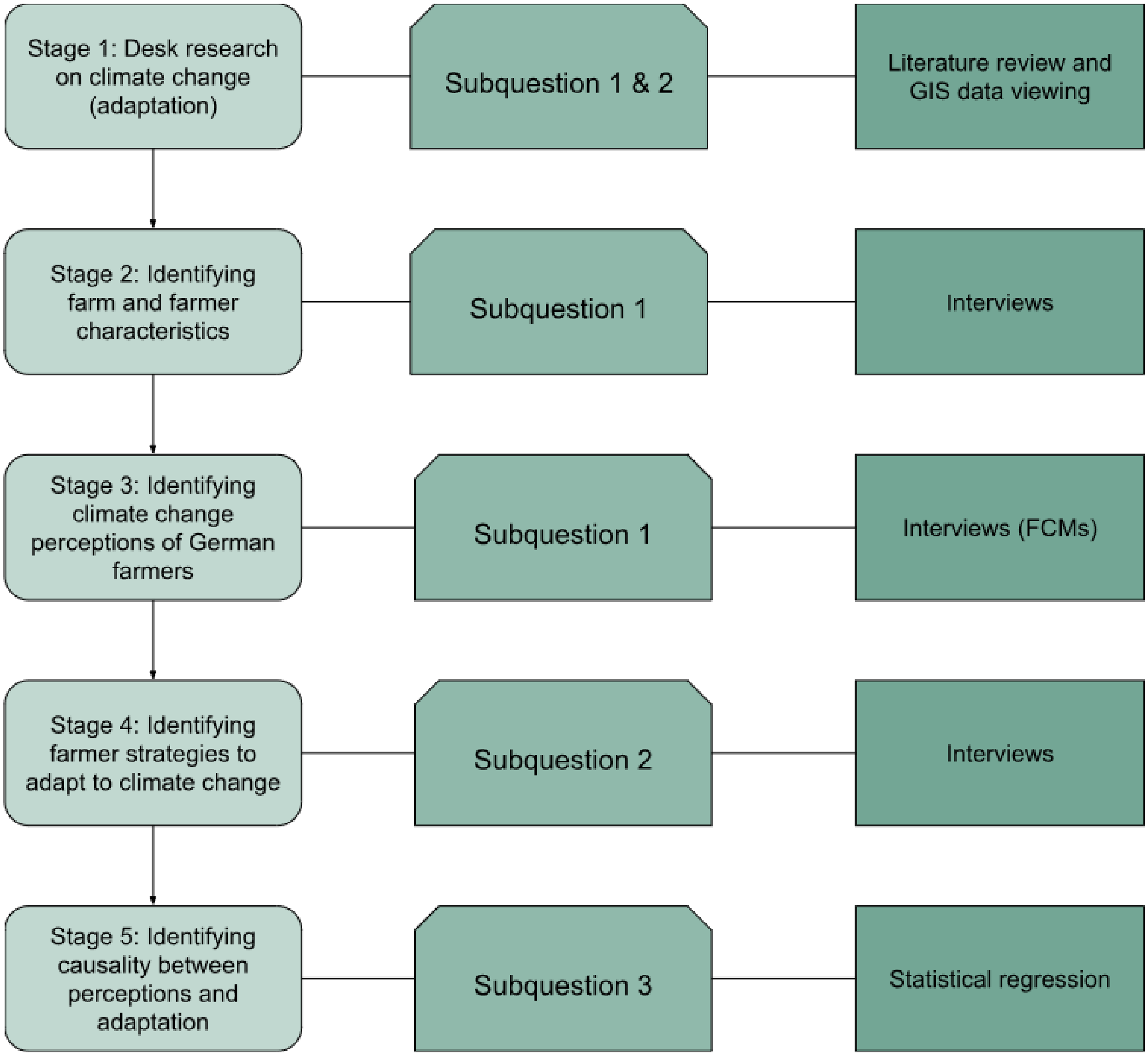


Figure 5: Research framework with 5 stages and their corresponding sub-questions and methods

3.4 FUZZY COGNITIVE MAPS

In this section, the main method of this research, fuzzy cognitive maps will be explained. First, there is a section with the background, then the process of the interviews, and then the analysis.

3.4.1. BACKGROUND

Fuzzy cognitive maps (FCM) is an approach used to portray a complex system and its relationships and inner complexities. It is a digraph used to describe a system. The different nodes in the system represent different variables and are connected by arrows. Hereby, relationships can be shown between variables and causality can be explored. FCMs are used in complex scenarios and are a good method for connecting vague concepts (Felix et al., 2017). Fuzzy cognitive maps have advantages when used for research. They are especially useful because they make sense of abstract variables and modelling relationships that are not known with certainty. Fuzzy cognitive maps form a qualitative map of how a complex system works (Özesmi & Özesmi, 2004). Using this method will show the wide array of different perceptions and the ways they interconnect with each other (Teixeira et al., 2018).

3.4.2 PROCESS DURING INTERVIEWS

In this research, Fuzzy Cognitive Maps are used for the first sub-question; what characterizes farmers' perceptions. In fuzzy cognitive maps, there is a central variable, and other variables that influence or are influenced by the central one. This is portrayed by arrows going from one variable to another (Teixeira et al., 2018). During the interviews, farmers were asked to name all variables they could mention that are related to climate change and that have influence on their business. Every farmer could decide for themselves how much weight will be put on the connection of this variable with the central ones. There were two central variables that are related to each other. The first is climate change. This one only had outgoing arrows, to other variables, such as, extreme weather, and drought. These arrows were the change that the farmers had seen over the last years, so how much this phenomenon has increased or decreased. If a farmer mentioned drought for example, and gave this arrow 5 as a number, then the droughts have increased drastically.

The second central variable was the impact on farm business. This variable only has ingoing arrows coming from the variables produced by climate change. The risks posed by these problems to the farmers were weighted with a number between minus five (very negative) to plus five (very positive). Farmers came up with their own variables, after being asked the question: What effects from climate change have you experienced in the last 10-20 years, and what is the influence of these effects on your farm?

While it is possible to do fuzzy cognitive maps in focus groups, interviews with a single participant have the preference of researchers since it is more in-depth and power imbalances among participants are non-existent (Özesmi & Özesmi, 2004). The process of making these maps was very interactive, where the farmers constructed their own maps, and the process was facilitated by the researcher, together with other researchers from the overall project and a native German speaker. The maps are all self-constructed by the participant on an A0 piece of paper with the help of Post-its. Some interviews were done online, and Excalidraw was used to make the maps. This tool gives both parties (the interviewer and the interviewee) the option to draw on the map.

3.4.3. ANALYSIS

After the interviews were completed, the analysis of the maps started. For the analysis, several factors were looked at and calculated. First, the number of variables put on the map by each farmer and the average of all farmers. Second, the sum of the weight of all arrows to the central variables. Third, the type of variables. The three types are: receiver (only ingoing arrows), transmitter (only outgoing arrows) and ordinary variables (both ingoing and outgoing arrows). Lastly, the maps are analysed by using graph theory.

By using graph theory, a way to quantitatively analyse the maps is possible. First, the maps are transformed into adjacency matrices, where the strength of the connections between the variables and the arrows is calculated. This was done by coding the variables into square matrices. When there is a connection between two variables, the value of this connection is then coded into the square matrix. Using graph theory also makes it possible to calculate more indices, for example, that of the clustering coefficient which will show how sparse or dense the map is, which is an index for the complexity of the perception (Özesmi & Özesmi, 2004; Teixeira et al., 2018). Moreover, density, indegree, outdegree, centrality (of the variables), and number of receiver variables were also used for the analysis. The first index, the density is the number of connections divided by the maximum number of connections possible between N variables (Hage and Harary, 1983). The second index, the centrality is the summation of its indegree (in-arrows) and outdegree (out-arrows). To analyse the individual variables and their relation to others, the centrality is important. It shows the connectivity with other variables, and how overall central the variable in the farmers' perception is. The number of receiver variables portrays the number of outcomes that are possible, since they are outcomes, and they do not cause other variables (Özesmi & Özesmi, 2004). For these calculations, the programme of FCMapper was used. In order to be able to use this programme, the values first had to be changed into values from -1 to 1. This way of analysis makes it possible to do regression with the results and test significance, since the complexity of the map will show the complexity of the the perception. This will be further explained in the next paragraphs.

Then, the maps are brought together into one big social map to look for similarities and differences. These FCMs are used to shape the perceptions of the farmers, and therefore answer and analyse the first sub-question. In short, perceptions are measured in the form of interviews, of which fuzzy cognitive maps were made. When all the data was collected, these maps were then analysed. The second and third sub-questions are answered using the values of the fuzzy cognitive maps as well. The FCMs method is a combination of both qualitative and quantitative. It still focuses on experiences and perceptions, but it also is used to analyse the data quantitatively, by means of showing how certain factors impact others based on graph theory (Jetter & Kok, 2014; Özesmi & Özesmi, 2004).

To make all the variables fit well in the social map, some variables had to be aggregated. Even though there was great diversity in the answers given by each individual farmer, there were common variables. But, to make the list of all the variables and the number of times they were mentioned, some variables had to be aggregated into one variable. This means merging variables that had the same meaning into one. This was done by selecting those variables that are similar to one another, or by looking at the map. For example, some farmers only mentioned 'erosion' but made the connection on the map with heavy rain. This variable was then changed to water erosion. A table of the entire list with all the variables can be found in the appendix.

Out of the Excel sheet with the social map adjacency matrix, the social map 2d model was made. By transforming the Excel sheet into a net-file the data could be imported into Pajek and represented visually in the programme. Since the social map has a high number of variables, some variables were left out of the visual representation of the social map. This was done so a clearer and more concise picture could be shown. The cutoff was done based on the centrality of the variables. All variables with a centrality below the number of 0,16 were taken from the map. Before the cutoff, there were 47 variables, after the cutoff, there were 30. This makes the map more readable, and cuts out the variables that were not mentioned often, or given much weight.

3.5 GIS MAPS AND FIGURES OF THE OVERALL PROJECT

Since this thesis is part of a larger project, other information is also found by the other people in the project. This information and figures gathered will also be represented in this research since it gives important findings about the reserve. These findings are important to give some background information about the findings on the farmers overall in the reserve.

Excel sheets were made of the Biosphere-reserve, which included every farmer that owns land, there is on the reserve. This is a total of 83 farmers on the reserve. Again, these are only the farmers who own land. Some of the land is also owned by cooporations. Some farm(er) characteristics were explored on the map. For example, the crops planted by the farm or the number of animals. The Excel sheet with all the farmers was later used to look up farmers and their businesses online and contact them when their contact information was also available online.

3.6 INTERVIEWS

The data was collected in the form of interviews, in which the data sources were farmers in the biosphere reserve Schorfheide-Chorin. During the interviews, the fuzzy cognitive maps were constructed. For the answer to the first sub-question, fuzzy cognitive maps were used. As explained in the last section, perceptions were operationalized by analysing the FCMs. Contrasting perceptions were explored and operationalised. Central in this part of the interview was climate change and how the farmers perceive its impact on their farms. For example, the risk they experience from the decrease in rain or the loss in biodiversity. Moreover, questions in the form of a questionnaire will be posed regarding the farmer's and farm's characteristics as well as adaptation practices. Questions concern the farm size and gender of the farmer and the nature of the adaptation practices they employ. Adaptation practices were given as a reaction to the issues posed by climate change that the farmers talked about earlier in the interview.

The interviews were mostly conducted in the farmers' native language: German. At almost every interview there was a native German speaker as well as the researcher. In total, 15 interviews were conducted. 13 of those were farmers where the impact of climate change on their farm was talked about, and the way they respond to this challenge. 2 of the interviewees were key experts that have an organizational or overseeing role. In these interviews, climate change adaptation was the main subject, and how the experts aid the farmers in adapting to climate change, and what are common measures. The characteristics of the interviewees will be portrayed and analysed in the results section.

Table 2: Interviewee types that were represented in the research. 2 of the interviewees were key experts that have a more overview role, and 13 farmers.

Interviewee type	Number of interviewees
Key expert (1 from the federal government, and 1 from the organization of the reserve)	2
Farmer	13

The interviews with the farmers were mostly open, with only a few questions prepared. First, the questions regarding the farm and farmer characteristics were asked. So how many hectares do you have? Are you organic or conventional? Some other questions regarding the farm were also asked, like how many animals do you have or what type of crops do you grow? Then: what have you experienced from climate change in the last 10-30 years (depending on the farmer's age). This question started the process of farmers naming variables for the fuzzy cognitive map. Then questions were asked based on the map. Lastly, the question of what type of climate change adaptation measures they employ was asked. The full interview guidelines can be found in Appendix 1. Since the interviews were quite open and there was space for discussion and own input by the farmers, in many cases, farmers did bring their own opinions on other topics up as well. This happened with barriers to adaptation. Many farmers mentioned the political nature of climate change adaptation and how that is also an obstacle. The farmers mentioned how unsatisfied they are with policy-makers and how that prevented them from adopting climate change adaptation measures. Since this topic was not prepared for, but was important to the research, it has been included in the results section.

Out of the 15 interviews done, 2 were done online, while the other 13 were in person. This always happened at the farmer's or key expert's house or office. During the process of the interviews, some farmers also led us around and showed us their farms. Here I could also see some of their equipment and for example cooling systems in stables. Below are some photos that I took during my time on the farms.

Figure 6: Sheep on a farm (Author's own)

As can be seen in the photo, the area is very forested and has many animal pastures. Many of the animals in the reserve have outside space to roam. At the same time, there were also large stables for animals to be inside (Figure 7).

Figure 7: Cows on a farm (Author's own)

3.7 THEMATIC CONTENT ANALYSIS

For the analysis of the qualitative parts of this research, climate change adaptation strategies employed, barriers to climate change adaptation and the qualitative part of climate change perceptions, a thematic content analysis was done. Here the adaptation strategies and which goal they are implemented with are analysed, the goal they serve goes back to the perceptions, and which outcome of climate change they are adapting to. This information is later used again for the analysis of the link between perception and climate change adaptation. The barriers to climate change adaptation were also analysed and grouped into themes. This gives a clearer overview of what the issues are.

In thematic content analyses out of interviews, common themes are identified. In this case, this is climate change adaptation measures and what issue of climate change they tackle as well as the barriers the farmers face. This method is performed on qualitative data (Anderson, 2007). This method is suitable for this chapter of the results since common themes and strategies among the farmers can be found. Since the adaptation strategies will be reduced to a number later for the regression, a more in-depth analysis is important to be done in giving context to the number.

3.8 STATISTICS & LINEAR REGRESSION

There are two statistical methods used in this study. First, statistical tests for the significance of the influence of farmer characteristics on perceptions were performed. There are several statistical tests to gain insight into whether the results from two different groups are different enough to be significant. Since the results of the study are not normally distributed, a Wilcoxon test was chosen to test the significance in this study. Based on these tests, it could be concluded whether the results have no significance (p= >0,1) a weak match or a trend (p=<0.1 but >0.05) or significance (p=<0.05) (Bailey & Gribskov, 1998). This will determine whether the farm characteristics (organic management or not, and farm size) and the farmer characteristics (age) have an influence on the perception of climate change.

Lastly, a linear regression was performed. This method was used for the second and third sub-questions. Statistical regression is used to investigate a relationship between two variables, in most cases a causal one. It is a quantitative method. Typically, the formula of a regression follows: $I = \alpha + \beta E$. In which I is the dependent variable. a is a constant, β is the slope of the regression and E is the independent variable. (Sykes, 1993).

To make a statistical Wilcoxon test, a hypothesis must be made. In the case of sub-question 1, this hypothesis is that farm(er) characteristics have a causal relationship with perceptions, namely, that characteristics influence perceptions. This hypothesis is then tested in a programme (R), by putting data gathered in the interviews. This data was indices regarding the complexity of the map, such as the number of variables and connections, with the data gathered about the farm(er) characteristics. The programme is then constructed to calculate the probability of a significant difference between the two groups. For example, perception complexity has a causal relationship with age. This would then be the case if, for instance, older farmers have a significantly higher complex perception of climate change effects on their farms than younger farmers. Whether this was the case will be portrayed in the results.

In sub-question 3, the hypothesis was that perceptions influence the adoption of adaptation practices. To gain an answer to this sub-question, a linear regression was done. To make the regression models, the different variables (concepts) have been given numerical values. This was done by using the fuzzy cognitive maps, and the answers to the questionnaires. From the analyses of the fuzzy cognitive maps, numerical values for the concept of perceptions arose, for example, the complexity of the map. For the concepts of characteristics and adaptation practices, the questions were asked directly to the farmers. First, the farm size was asked, and then whether they were organic or not. Questions regarding the adaptation practices were open, i.e. How many adaptation practices do you employ? The number of adaptation practices was then taken from this question as well as others, coming to a certain number for each farmer. In this way, a regression could be done using the numbers for the complexity of the perceptions, as well as the adaptation practices, and causality was then tested. For sub-question 3, the hypothesis was that farmers with a more complex perception of climate change also adopt more adaptation practices. This causal relationship is then shown by using the answers from the interviews and checking with R whether the causal relationship is significant (p= less than 0,05). This would be the case if many farmers with a complex perception have implemented more adaptation practices and vice versa. Therefore, using regression proved an effective method to test for causal connections.

3.9 VALIDITY AND LIMITATIONS

Since this research is highly specified on German farmers and their unique conditions, the research is not highly applicable in other countries or areas. The reserve where this research takes place is also less representative of Germany. The average number of organic farmers and pesticide-free farmers is significantly higher than the German average. This makes the research less widely applicable.

Since the research is focused on climate change effects and climate change adaptation, mostly farmers with already a broad perception of this problem reacted to the invitation. This was especially the case since our main contact point that brought us into contact with other farmers was an organic farmer. Through him, some other interviews were done, but this was with organic farmers. Moreover, since the theme of the project is climate change adaptation, farmers responding to our call, were already more involved with this. In order to combat this problem, many conventional farmers in the area were personally approached by the researchers to ensure that all types of farmers with all kinds of different opinions and perceptions were involved. This strategy paid off in the end, as also conventional farmers, as well as farmers with differing perceptions of climate change responded to the call, creating a more representative sample.

During the interviews, three farmers did not believe in climate change. While some did still feel the consequences of climate change, they were hesitant to ascribe this phenomenon to human intervention and did not see it as something out of the ordinary. Therefore, with these farmers, no fuzzy cognitive map was made since they have no perception of climate change. However, since it is vital to include these farmers in the research, their ‘perceptions’ will be included in the discussion on the climate change chapter of the results. In the climate change adaptation chapter, they will be taken in the results since they did have adaptation measures.

4. RESULTS

In this section, the results of the research are portrayed. There are three parts of the results. Part one is the results regarding farmer perspectives on climate change. Part two is the results of climate change adaptation. Part three goes into the link between perceptions and adaptation.

4.1 FARMER PERCEPTIONS OF CLIMATE CHANGE

In this first part, the first part of the results are portrayed. These results are specifically about the farmer perspectives on climate change, and the underlying characteristics influencing these perceptions. First, a literature study was done to discover farmer perceptions mostly in Germany. The findings of this literature study can be found in the theoretical framework. Then, several GIS maps and Excel sheets, previously constructed by other project members, were looked at. In these maps, several farmer characteristics were displayed. These maps cannot be shared in this thesis for data protection reasons. Then, interviews were conducted to find out more about farmers' perceptions of the Schorfheide-Chorin biosphere reserve. The results of the perceptions of farmers are based on the Fuzzy Cognitive Maps as well as information in the interview itself. A possible connection between the perceptions and the characteristics is explored as well. This is done by a regression comparing the complexity of the perception, with characteristics such as organic farm or not, age and farm size.

4.1.1 CHARACTERIZATION OF THE RESERVE

Information gathered by other researchers in the overall project will be taken into account to characterise the reserve that the farmers that were interviewed inhabit. Since organic farming plays a role in the perceptions and underlying characteristics, organic farming in the reserve was explored.

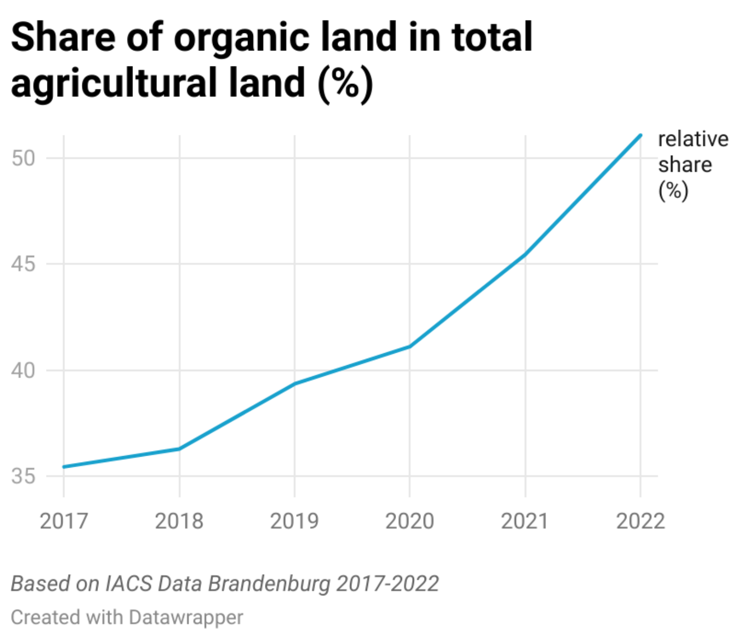


Figure 8: Land percentage of organic farms in the Schorfheide-Chorin reserve is going up, covering more than 50% in 2022

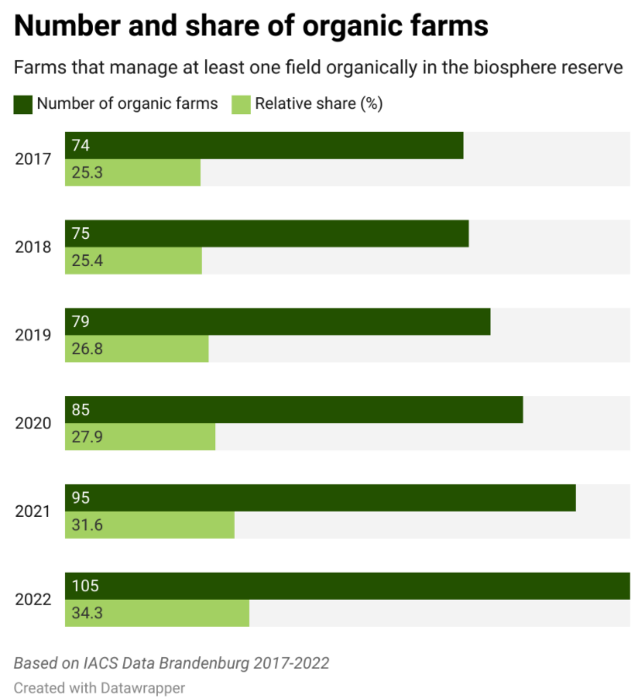


Figure 9: The number of organic farms and its relative share in the reserve

As can be seen in Figure 8, the percentage of organic farms in the reserve has expanded exponentially in the last few years. Moreover, the percentage of organic farms is much higher than the average in Germany. However, in Figure 9, it can be seen that the actual number of organic farms is lower than the area under organic farming, which means that the organic farms on average have a high number of hectares. This can also be attributed to the fact that a large amount of land belongs to the ecovillage, which only farms organically.

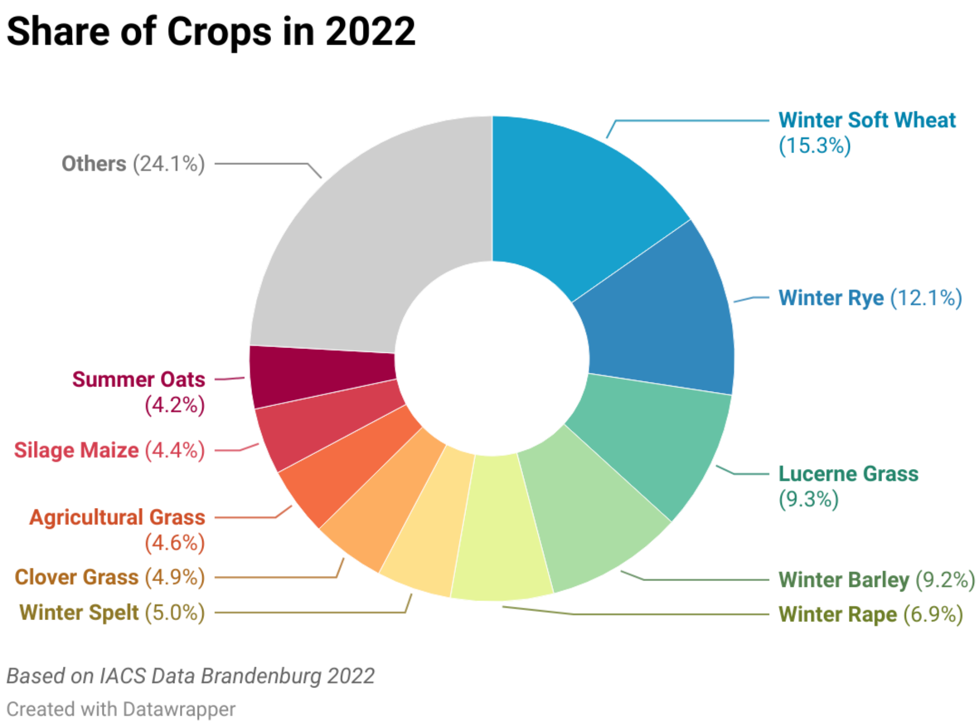


Figure 10: Share of crops 2022 in the reserve with winter crops being much more widely grown than summer crops

As can be seen in Figure 10, many different crops are being produced in the area. Most of these crops are winter crops. Later in the climate change adaptation parts of the results and the discussion, more will be explained about this.

4.1.2 FUZZY COGNITIVE MAPS

In total, 13 farmers were interviewed, of which 10 complete fuzzy cognitive maps were made. Three farmers did not believe in climate change, they believe what is causing weather changes is simply that: weather. One of these farmers did not think there was any change in weather at all. The other two thought the weather simply changes throughout the years, this is something natural. These farmers have a perception of climate change, namely, it does not exist in the way that most science agrees upon its existence. These views are valid and need to be considered as well. However, since the fuzzy cognitive map could not be made with these farmers, their perception of climate change will be put to zero in numerical terms for the purpose of this analysis. Since some of these farmers did employ adaptation techniques, albeit for what they perceive as weather adaptation techniques, their adaptation techniques will be taken into account.

Of the 10 farmers that do have a complete map, the numerical values of their perception need to be calculated by using indices based on the maps. As mentioned before, each farmer placed their own variables on the map, no pre-made variables were used. Therefore, the number of variables that were put on the maps were varying. This number ranged from 4 to 14. The average number of variables is 10.8. The number of variables that was most common was 11, with 6 farmers having 11 variables on their map. When a farmer mentions more variables, this means the farmer has a more complex perception of climate change. Second are the connections. The average number of connections was 17.3. These are arrows going from climate change to outcome variables, from variables to influence on business and in-between variables. This ranged from 7 to 23. Third is the weight of the connections from climate change (outdegree). This is the counted weights of the connections that go from climate change to variables, and in between variables. This represents how much climate change the farmers perceive. This number was 32.35, ranging from 18 to 52. Fourth is the weight of the connections to influence on business, which is the indegree of influence on business. These are the weights of the arrows going from the variables caused by climate change to the influence on the business. These arrows can be positive or negative, since the influence can be both as well. The average value here was -12.2, with a range of +1 (so climate change altogether is slightly positive) to -28 (climate change is very negative). These values can be seen in the table below.

Table 3: The average number of variables, connection, weight of climate change and indegree of influence on business of the farmers

	Average value farmers
Number of variables	10,8
Number of connections	17.3
Weight of climate change (outdegree)	32.35
Indegree of influence on business	-12.2

INDICES

Of all the fuzzy cognitive maps, adjacency matrices were made. To form one large social map (a map of all farmers), the matrices were put together. This was done by summing up all of the connections and dividing them by the total number of farmers. This results in a fuzzy cognitive map that has all variables mentioned, and all connections between all of those variables. This complete social map of all the variables and connections mentioned by the farmers can be found in Appendix 3. Moreover, a list of all the variables mentioned by the farmers, and the number of times mentioned by the farmers can be found in Appendix 6. This is the original list without the aggregated values or translations.

In the table below, the variables, as well as the outdegree, indegree, centrality and number of times they are mentioned are shown. The density, total number of factors and connections can also be found. The first two variables on the list: Climate change and Influence on the business, were already present on the map when the interview began. These variables therefore have the highest centrality since they were on every farmer's map. Drought is the variable that was most mentioned by farmers without it being prompted. In the original table, after aggregating, the total number of variables was 47 and the total number of connections, was 100. To make the table more readable and give a better overview, the least mentioned variables with the lowest centrality have been cut out in this table. The full table with all of the variables can be found in Appendix 7.

Table 4: List of all the variables mentioned together with: indegree, outdegree, centrality and number of times mentioned by the farmers with climate change and influence on business having the highest centrality and being the most mentioned.

Density	
0,045269353	
Total Nr. Factors	**Total Nr. Connections**
47	100

Concepts	Outdegree	Indegree	Centrality	Number of times mentioned
Climate change	4,08	0,00	4,08	10
Influence on the business	0,00	3,66	3,66	10
Droughts	1,43	0,75	2,18	9
Longer growing season	0,45	0,46	0,91	7
Heavy rain	0,52	0,36	0,88	6
Heat	0,38	0,30	0,68	5
Fluctuations in precipitation	0,40	0,18	0,58	3
Water erosion	0,24	0,26	0,50	4
Milder winter	0,12	0,35	0,47	5
Poor conditions plant growth	0,24	0,20	0,44	3
Higher temperatures	0,20	0,18	0,38	3
Extreme weather events	0,13	0,24	0,37	2
Stress (Animal)	0,18	0,14	0,32	2
Unplannable	0,12	0,18	0,30	3
Higher earnings volatility	0,12	0,16	0,28	1
Warmer in summer	0,16	0,12	0,28	2
Yield decline	0,08	0,18	0,26	3
Microorganisms die	0,06	0,16	0,22	1
Winter more dry	0,16	0,06	0,22	1
Transformation processes	0,10	0,10	0,20	1
Performance depression	0,04	0,16	0,20	2
Less frost	0,04	0,14	0,18	2

Earlier spring	0,10	0,06	0,16	1
Drought stress in plants	0,00	0,16	0,16	1
Longer periods with rain	0,02	0,14	0,16	1
More precipitation in winter	0,02	0,14	0,16	2
Higher temperatures flowering phase	0,06	0,10	0,16	2
Incline water consumption	0,08	0,08	0,16	1
Hot ground surface	0,08	0,08	0,16	1
Heavy soil cultivation	0,08	0,08	0,16	1
Plant diseases	0,08	0,08	0,16	1

In Table 5, the number of transmitter, receiver and ordinary variables are shown. As can be seen, most variables are ordinary, meaning they have a receiving arrow as well as an outgoing arrow. There is only one transmitter variable, which is the central variable of climate change.

Table 5: number and percentage of transmitter, receiver and ordinary variables

Nr. Transmitter	Nr. Receiver	Nr. Ordinary
1	**6**	**40**
% Transmitter	% Receiver	% Ordinary
2,12766	12,76596	85,10638

Before putting the variables on the map, coloured groups were made to group similar variables that connect often with each other. These groups follow the themes that can be found in the variables. These themes are based on the category of climate change outcome they correspond with. Some themes are embedded within the groups. The colours and shapes are used in the visual 2D map. As can be seen in the figure below, there are 4 colours that represent the different variables. The first colour is yellow, this is the precipitation group. This group has all the variables that have anything to do with too much, or a lack of precipitation. Within this group, there is the drought theme and the heavy rain theme. The blue group is the group representing the socio-economic effects of climate change. This includes the economic theme and the social theme. The green group is the group on temperature. This has everything to do with the rising temperatures and what this causes. This group has the heat theme embedded. The last group, the red group has to do with the change in seasons. This means longer seasons or different seasons.

The 2D model of the aggregated social map of all farmers can be found in Figure 11. The size of the variables represents the centrality. In the figure, climate change is the variable that causes the other variables which are outcomes of climate change, therefore it is the most central variable. This is the largest circle in the figure and can be found at the top. All arrows point away from this variable since all influence comes from climate change, since this study does not discuss what influences climate change itself. At the bottom, there is the second largest circle, the variable with the second largest centrality, Influence on business. This represents the influence of the outcomes that climate change has on the farmers and their businesses. As can be seen, influence on business only has incoming arrows, since it is an end-outcome. Other variables that were often mentioned and are central in the figure are droughts, longer growing seasons, heavy rain and heat. The size of the arrow represents the strength of the connection from one variable to another. This means, that the bigger the arrow, the more often this connection was mentioned and the higher the weight of the connection was. If the colour of the arrow is red, the value of the connection is negative. If the colour is black, it is positive. The strongest connections are to droughts and longer growing season, which are thereby the most and strongest perceived outcomes of climate change by the farmers, which means that they were often mentioned and their arrow from climate change has a higher value on average. The arrow from droughts to influence on business is also large, since many farmers call there to be a connection and this connection to be strongly negative. At the same time, the biggest positive arrow comes from longer growing season, which had a largely positive influence on the business.

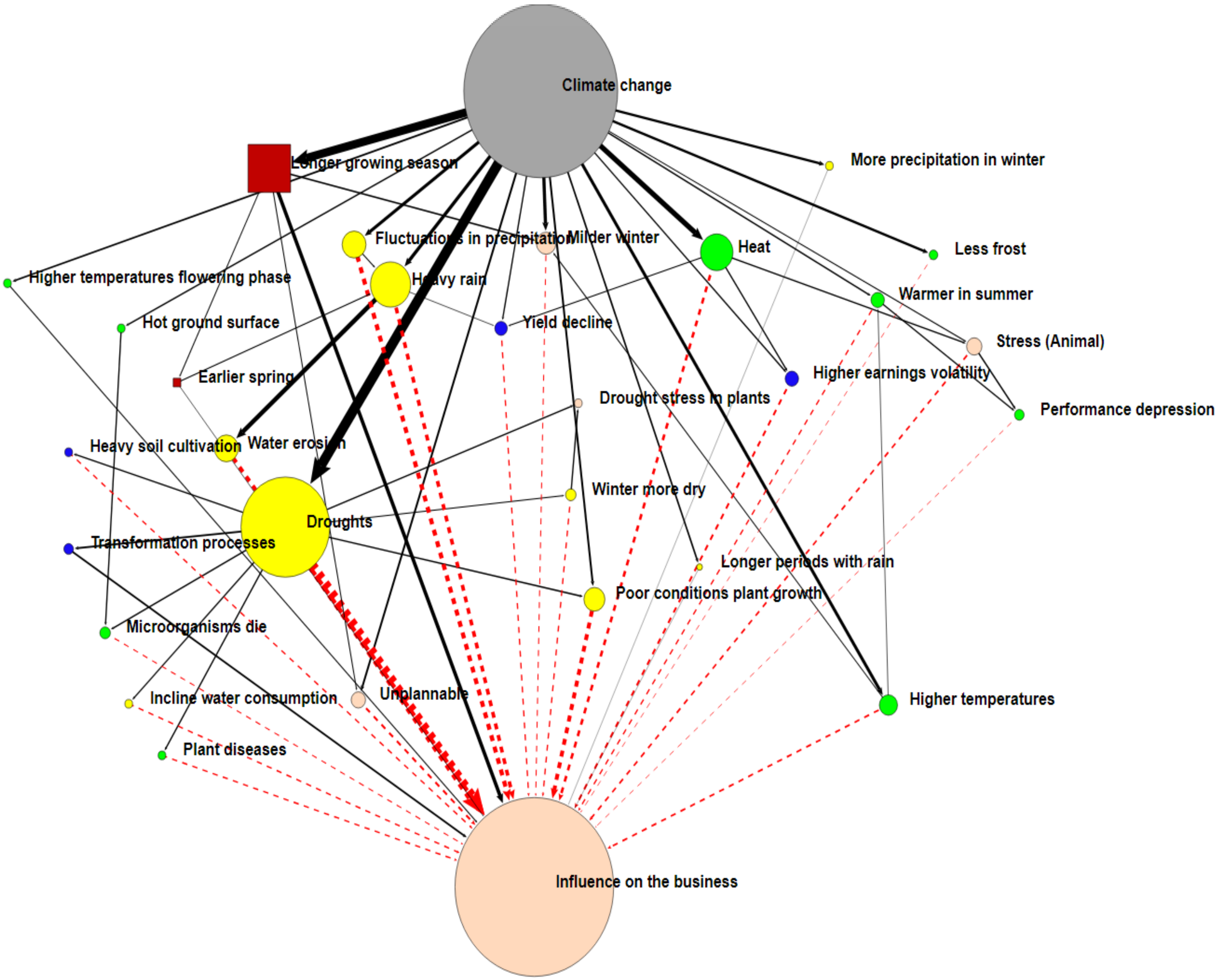


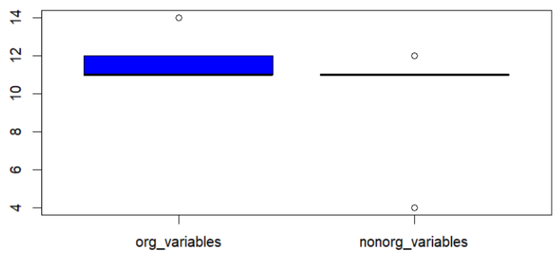
Figure 11: Social map of all variables and connections made by 10 farmers, in which the size of the variables represents centrality, and the size of the arrow represents the strength of the connection. Climate change and influence on business are the largest and therefore have the highest centrality and are most often mentioned. The thickest arrow goes from climate change to droughts, since this connections was most mentioned and has the most weight. The yellow color in the figure represents all variables that cover precipitation, the green represents heat, the blue socio-economic factors, and the red seasonal changes.

4.1.3 FARM(ER) CHARACTERISTICS

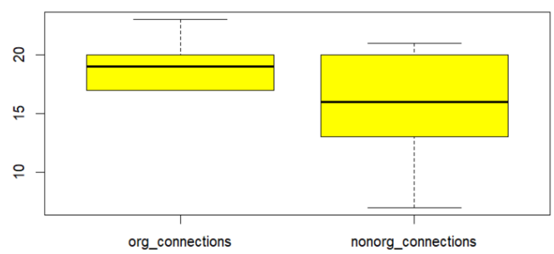
In this section, groupings in farm characteristics are portrayed, and the differences between the groups of farmers when comparing the FCMs. Since according to the literature, these farmer characteristics influence the perceptions, in this part of the results, the values for the FCMs for each group are compared. First, the average number of variables on the map between the groups is compared, then the average weight of the connections, the average weight of the arrows going from climate change and between the different variables, and finally the average indegree of the influence on the business. First, the different values were put on a boxplot to see the distribution of the different values within the farmer group. Then, to find out whether the farm and farmer characteristics have a significant influence on the perception of the farmer, a Wilcoxon test was performed.

First, every farmer was asked whether they farmed organically or not. Of the 10 farmers with an FCM, five were organic and five were non-organic. Of the three farmers without a map, one was organic and two were not. This percentage is in line with the overall percentage in the reserve in terms of land as can be seen in Figures 8 and 9, and is therefore representative when considering that the larger farms will also have more employees. Second, the age of the farmers was also taken into account. These were made into two groups. The age of farmers was not asked directly, since this can be a sensitive topic. Some farmers did mention their age, but if they did not, an estimation was made. Five farmers are below 49, while five farmers are above. Third, every farmer was asked how many hectares their farm has. All constellations can be possible, some rented, some owned, all owned, or all rented. Most farmers owned some land and rented other parts, or rented out part of their land. The farm sizes were divided into two even groups, one with farms of more than 850 hectares, and one with less. Each group also has five farmers.

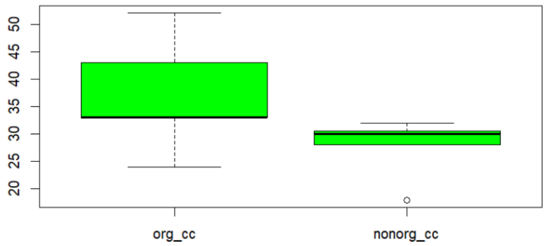
In the figure below, the distribution of the values in each group for each characteristic can be seen. As the boxplots show, there are some outliers within the groups, and the distribution within the groups can be very large. This is only not the case for the number of variables groups (12a, 12e, 12i), the numbers are in a very small range, with one outlier. However, no large differences between the groups can be seen.



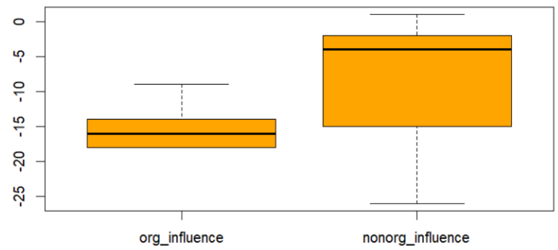
a. Comparison of number of variables organic and non-organic



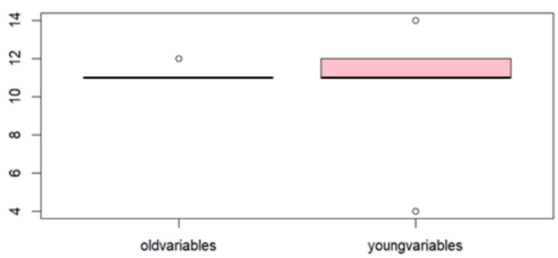
b. Comparison of number of connections organic and non-organic



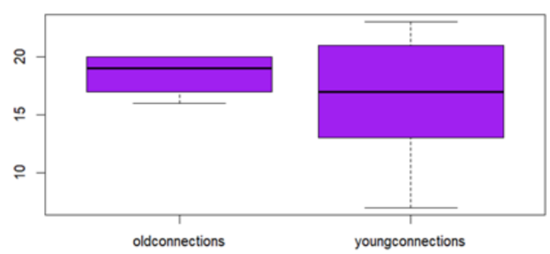
c. Comparison of weight of climate change organic and non-organic



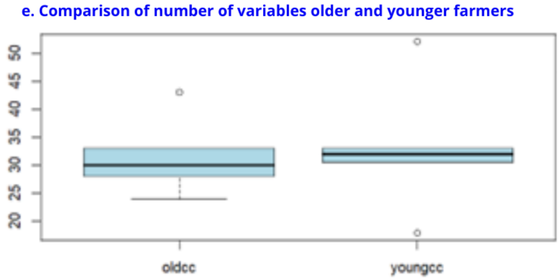
d. Comparison of indegree influence organic and non-organic



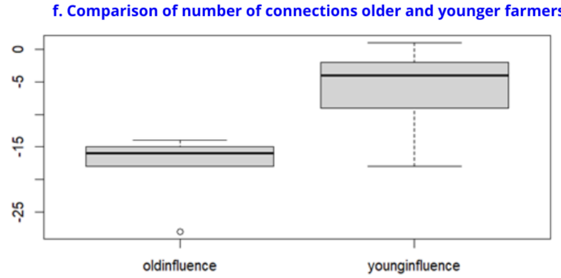
e. Comparison of number of variables older and younger farmers



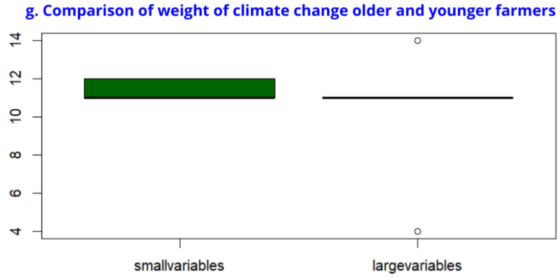
f. Comparison of number of connections older and younger farmers



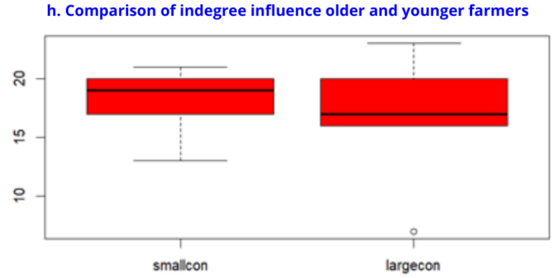
g. Comparison of weight of climate change older and younger farmers



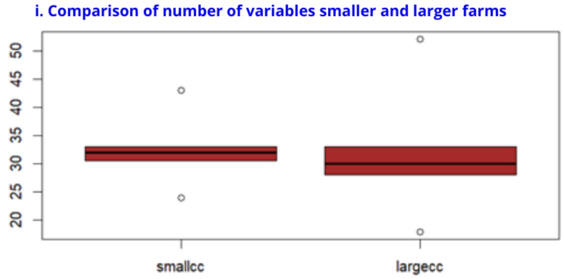
h. Comparison of indegree influence older and younger farmers



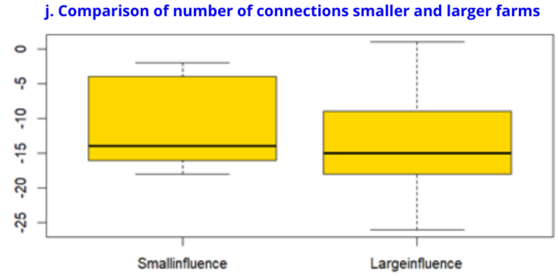
i. Comparison of number of variables smaller and larger farms



j. Comparison of number of connections smaller and larger farms



k. Comparison of weight of climate change smaller and larger farms



l. Comparison of indegree influence smaller and larger farms

Figure 12: Boxplots of the distribution of all values from the different farmer groups based on management style (organic or conventional), farmer age, and farm size. In many of the boxplots, overlap between the different groups can be seen. On the Y-axis, the number of variables, the number of connections, the weight of climate change, and the indegree of influence on business are displayed.

In Table 6 below, the mean of each set of values from each group of farmers is calculated. Next to this, the standard deviation is shown. To find out whether the differences that can be observed in the table make a significant impact on the perception, a series of tests were done. As can be seen, with a p= <0,05 significance taken, none of the results are significant. However, when the p-value is below p= <0,1, a weak match or trend can be seen. This is the case for the weight of climate change experienced by organic and non-organic farmers, as well as the difference in the indegree of influence on the business between younger and older farmers. In general, the P-values in the organic or non-organic group are much smaller than the values in the farm size group. In the age group, the P-value for indegree of influence on business is the smallest in the sample, indicating the strongest impact, but the other values are also inconclusive. In Figures 12c and 12h, it can also be seen that the boxplots of these two somewhat significant P-values are different from the others. These are the only boxplots that have little to no overlap.

Table 6: Groups of farm characteristics, farm type, age of the farmer and farm size. None of the P-values are significant with a significance level of P= <0.05. Two values are P=<0.1 so here a link the can be found. This is the case for the difference between organic and non-organic farmers for weight of climate change, and younger and older farmers for indegree of influence on business

		Number of factors	Number of connections	Weight climate change	Indegree influence
All farmers		10.8±2.6	17.3±4.6	32.4±9.4	(-)12.1±8.4
Farm type	Organic (n=5)	11.8±1.3	19.2±2.5	37±10.2	(-)15±3.7
	Non-organic (n=5)	9.8±3.3	15.4±5.7	27.7±5.6	(-)9.2±11.1
	P-value	**0.3447**	**0.3443**	**0.0937***	**0.1756**
Age of the farmer	<49 (n=5)	10.4±3.8	16.2±6.4	33.1±12.2	(-)6.4±7.4
	>49 (n=5)	11.2±0.4	18.4±1.8	31.6±7.2	(-)17.8±5.7
	P-value	**0.906**	**0.9163**	**0.8125**	**0.0749***
Farm size	<850 (n=5)	11.4±0.5	18±3.2	32.5±6.8	(-)10.8±7.3
	>850 (n=5)	10.2±3.7	16.6±6.0	32.2±12.4	(-)13.4±10.1
	P-value	**0.7893**	**0.8335**	**0.7533**	**0.5807**

It was also planned to include gender, since the literature also shows there is some evidence of it influencing perception and climate change adaptation, but this research did not have a diverse enough group. Of all the farmers, there were two women.

4.2 CLIMATE CHANGE ADAPTATION OF FARMERS

In this section, climate change adaptation strategies by farmers are looked at. During the interviews, the topic of climate change adaptation played a big role. For the analysis of these results, a thematic content analysis was used to find patterns among the farmers on what type of adaptation methods they employ and what challenges they face.

4.2.1 THEMATIC ANALYSIS CLIMATE CHANGE ADAPTATION MEASURES FARMERS

In response to the climatic changes perceived by farmers, the interviewed farmers have adopted measures to mitigate these challenges. All 13 farmers have in one way or another responded to climate or weather changes. As mentioned before, three of these farmers did not see it as responding to climate change, but as responding to weather. When discussing the climate change adaptation techniques during the interviews, farmers were asked which techniques they have adopted and which techniques they are planning to or are considering to adopt. This is specified in the table. The measures have been grouped into an overarching method, with the more specific method or crop used. All together, 26 different adaptation techniques were used by 13 farmers. On average, the farmers used eight adaptation practices.

To come to this table, all climate change adaptation measures were put in a different table and then aggregated to the techniques seen in the table below. This full list can be found in Appendix 5.

THEMES

The adaptation techniques can be grouped into themes. These themes are based on what is being adapted to, and which problem caused by climate change is being tackled. For example, climate change caused water sparsity, and an adaptation technique to that would be irrigation. This method is used to find certain patterns in adaptation and what problem this adaptation technique tackles. By adding on the number of farmers who mention this it can be seen which problems are tackled the most and in which way.

The themes which were found in the adaptation techniques were: soil-drought adaptation, crop adaptation, heat adaptation, seasonal change adaptation, altering farmer techniques, economic measures, heavy rain adaptation, and last is the category of adaptation techniques that do not fit into other categories, but were mentioned by more than one farmer.

Table 7: Themes of climate change adaptation and techniques used in those themes, as well as the number of times mentioned, with the most common and important themes being soil drought adaptation, crop adaptation, seasonal changes adaptation and heat adaptation

Theme	Technique	Times mentioned
Soil drought adaptation	- Keep the soil covered - No-till or strip-till - Planting Hedges - Trying irrigation - Efficiently using rain - Prevent soil compaction - Water-saving weeding - Fertilizing with more water intake - Using liquid nitrogen fertilizer - Adapt grazing rotation	13
Crop adaptation	- Trying new crops - More weather appropriate crops - Adapt crop rotation - Diversifying/ Spread the risk	9
Seasonal changes adaptation	- Change harvest and planting times	7
Heat adaptation	- Cooling in stables - Shade (for animals)	6
Altering farming techniques	- Considering new farming types - Switching to organic - Direct seeding	5
Economic measures	- Buying new equipment - enlarge surface area - Give up parts of the business, or reduce the number of fields - Renewable energies	3
Heavy rain adaptation	- Drainage for heavy rain	2
Other	- Use the extra CO_2 in air for hummus build-up	2

4.2.3 CHALLENGES TO ADAPTATION

In the interviews, multiple challenges to climate change adaptation were mentioned. The biggest challenge that was mentioned by 10 of the farmers was the disconnect between the political people and the farmers. Tied into this is money. In this part, these challenges experienced by farmers are investigated more deeply. Knowledge collected by two key experts is also used. One of the key experts works for the Ministry of Environment of Brandenburg. The other is in the organization of the biosphere reserve.

POLITICS

The politics of agriculture was originally not a part of the research, and it was also not a question asked in the interviews. However, 9 of the farmers mentioned it with no stimulation whatsoever. This topic also plays a big part in climate adaptation, since part of that is being stimulated by the government through, for example, subsidies. Because some farmers mentioned it affecting their willingness and ability to adapt to climate change, it is important to explore this part as well.

Different topics regarding political issues were mentioned by the farmers. These topics have been grouped into subsidies, bureaucracy, lack of knowledge, and the decision-making being too centralized, creating a gap between farmers and decision-makers. These topics are portrayed in the table below. The number of farmers that mentioned this topic is shown next to it.

Table 8: Political issues experienced by farmers and the number of times mentioned. These issues regard subsidies, bureaucracy, a lack of knowledge and a gap between farmers and policy-makers. The most mentioned issue was the bureaucracy

Political issue	Number of times mentioned
Subsidies	3
Bureaucracy / too many rules	7
Lack of knowledge	3
Too centralized / Gap	5

SUBSIDIES

Different farmers feel like they are dependent on subsidies. By only giving out subsidies if the farmers farm in a certain way, or withholding subsidies, farmers feel like they are not in control of their own business. Farmers express a will to be able to live off the sale of their products, but this is not possible.

On the other hand, there are not enough subsidies for climate change adaptation. Many farmers express a desire for irrigation but say that it is too expensive. For other adaptation techniques, such as new cooling in the stable, or a diversification of crops and species, there is many times also no money. In the case of organic farming, this is for example, that glyphosate is still much cheaper than weeding mechanically.

Some farmers do mention the laws that are there, and that are positive. However, the money is simply not there to help them with the adaptation. They mentioned the need to adapt, to face the troubles that they are facing. But the right subsidies are not offered to them.

Overall, three farmers mentioned specifically their financial situation being bad. They stated clearly that they have no money for including measures to cope with climate change, and that they have worse problems to deal with.

"Adaptation is something good that comes from negative effects." While most farmers see this political pressure as something negative, some farmers were also positive about the change that is happening in agriculture, and the change in politics.

BUREAUCRACY

As mentioned by seven farmers, a burden of administration is placed upon them, caused by the bureaucracy that is present in Germany. This burden comes in different shapes.

One farmer mentions the logistical burden of diversification, which is proven to be a much-used climate change adaptation measure. The same is the case for an irrigation system. Some farmers have tried it, but the logistical burden was too heavy. An irrigation system takes much work and the plants have to be switched much, which all has to be documented. An added trouble for some farmers when it comes to irrigation are water rights. This brings extra administration as well, and some farmers cannot receive them. The bureaucratic process can be complicated and it is unsure which farmers receive the rights and which do not.

"It's like I almost have to have studied to be able to understand it." One of the farmers mentioned about the administrative burden. Multiple farmers showed us the binders of each year and the amount of paperwork they have to fill in.

On top of that, it gets worse every year, farmers experience the administrative burden becoming worse and worse, and the binders becoming thicker and thicker.

LACK OF KNOWLEDGE

It's not always easy for farmers to respond to the weather changes that are happening. Politics should have some sort of guidance for the farmers. However, instead, according to the farmers, they come up with solutions that are not very fitting to the local situation of the farmers. These decisions are made by people that have less knowledge of farming than the farmers themselves. They feel like they can make decisions themselves.

"They need to talk TO us, not ABOUT us." One of the farmers puts it into words. They feel like they are not included in the decision-making that is about them, and that the people in charge do not know enough about their profession. Farmers expect there to be professionals at the table making the decisions, but in their opinion, that is not the case.

TOO CENTRALIZED / GAP

While the problem of politics ties into a lack of knowledge, it is more specific regional knowledge that is missing in central decision-making. Many farmers also mentioned a gap between politics and farmers. This also results in unnecessary measures, and farmers feel unheard. The local climate and weather conditions are very different, even within the same farm, according to the farmers. Therefore, there should be more precise decision-making for the farmers, that fits their farm and their circumstances.

“Politics should look from business to business.” As many farmers mention, the conditions at every farm are different. So, the one-size-fits-all all approach of centralized decision-making is not enough for many of the farmers.

SOCIETAL / MARKET

Some farmers mention the difficulty of the organic market, and the consumer interest being too low for organic products. Another problem with the market is that products from abroad are devaluing the products from the local farmers in their opinion. This causes them to fear that they might be unable to sell their products, and therefore be wearier of investing in climate adaptation practices.

On the other hand, many organic farmers mention the market as a reason for switching to organic agriculture. It offers a more stable income, while the yields are lower, but it has been said that it is more resilient. A big organic ecovillage in the reserve makes the organic market for many farmers more secure.

There is a change in society. The farmers have different opinions on this transformation. Some see it as something good while others feel like “the change is going too fast.” One farmer mentions: “The market doesn’t go with the societal change and the transformation is too expensive.” Multiple farmers feel that if they would produce more sustainably, their products would be replaced by products from other countries. “We need stability.”

Others have criticisms on the direction society is going. Some farmers were especially negative about certain parties in the government, or the farmer cooperatives. The concept of climate change adaptation is still mostly pushed by more green-leaning parties, which some farmers have developed a dislike against. This could harm the image of climate change adaptation, and cause farmers to not engage with it, even though it might be in their best interest.

EXPERTS

Two experts were interviewed for this research. One of these experts worked for the ministry of the state of Brandenburg which the Biosphere-reserve is part of, and the other works in the organization of the biosphere reserve. Both are involved with the management of the reserve in one way or another.

THE MINISTRY

Key expert 1 is part of the political side of the reserve, and also helps with the implementation of the climate adaptation measures. As can be seen in the section above, the farmers experience a great disconnect and unhappiness with current policies and politicians. This interview was also performed immediately after the protests by farmers in Berlin. So key expert 1 was aware of the disconnect and said that there were efforts by the ministry to relieve this disconnect and try to reconnect with the farmers.

Secondly, the expert is aware of the bureaucratic problem that many farmers mentioned and is also a victim of this. However, this seems to be a Germany-wide problem without a clear solution.

The expert did have concrete knowledge about agriculture and the way farmers are farming. They also have a concrete action plan to progress climate change adaptation, actively stimulating and aiding farmers in doing so. This includes: the support of native and weather-adapted species, and research of species that might be better adapted. Secondly, insurance is important for farmers. For example, they provide hail, damage or frost insurance. They are also actively involved in research on droughts in the region.

What the key expert mentioned most was the consultation of farmers. On the website of the ministry, farmers can opt for a consultation on multiple subjects. Here, they can get help on what to do when their crops perish because of the droughts for example. There are also special consultations on soil erosion and the build-up of humus in the soil, or how to save the rainwater from winter for the droughts in the summer.

However, the initiative to take one of these consultations has to come from the farmers themselves. They have to take the first step to go to the website and ask for help. With the level of trust so low, and the perceived lack of knowledge in politics this willingness to help from the ministry is not fully used. This creates another challenge for climate change adaptation.

THE RESERVE

Key Expert 2 has a managing role in the organization of the reserve. This expert has personal contact with the farmers in the reserve. This expert is proactive in the reserve to promote climate adaptation as well as mitigation. The expert mentions projects that they do to stimulate farmers for example to use less pesticides or try to save water. While these projects have a more personal touch than those from the ministry, and are also initiated by the organization, the farmers do still have a choice whether to participate in the projects or not. The organization of the reserve has no power to force the farmers to farm organically or to stop using pesticides, there are no laws that prohibit farmers. “We try to communicate the benefits, tell them it is good for your soil, good for the climate.” Therefore, it is mostly the same farmers that are participating in the project, and actively stimulated to, for example, apply climate change adaptation measures. However, the fact that many farmers do participate, and have switched to organic or pesticide-free farmers helps a lot. “They see other farmers do it around them, and therefore apply the techniques themselves as well.” Hereby, climate change adaptation techniques are more normalized. As can be seen in the figure below that was taken at the museum of the Biosphere Reserve, the conventional and pesticide-free farms are quite clustered together. This supports the hypothesis from the expert that farmers are influenced by each other.

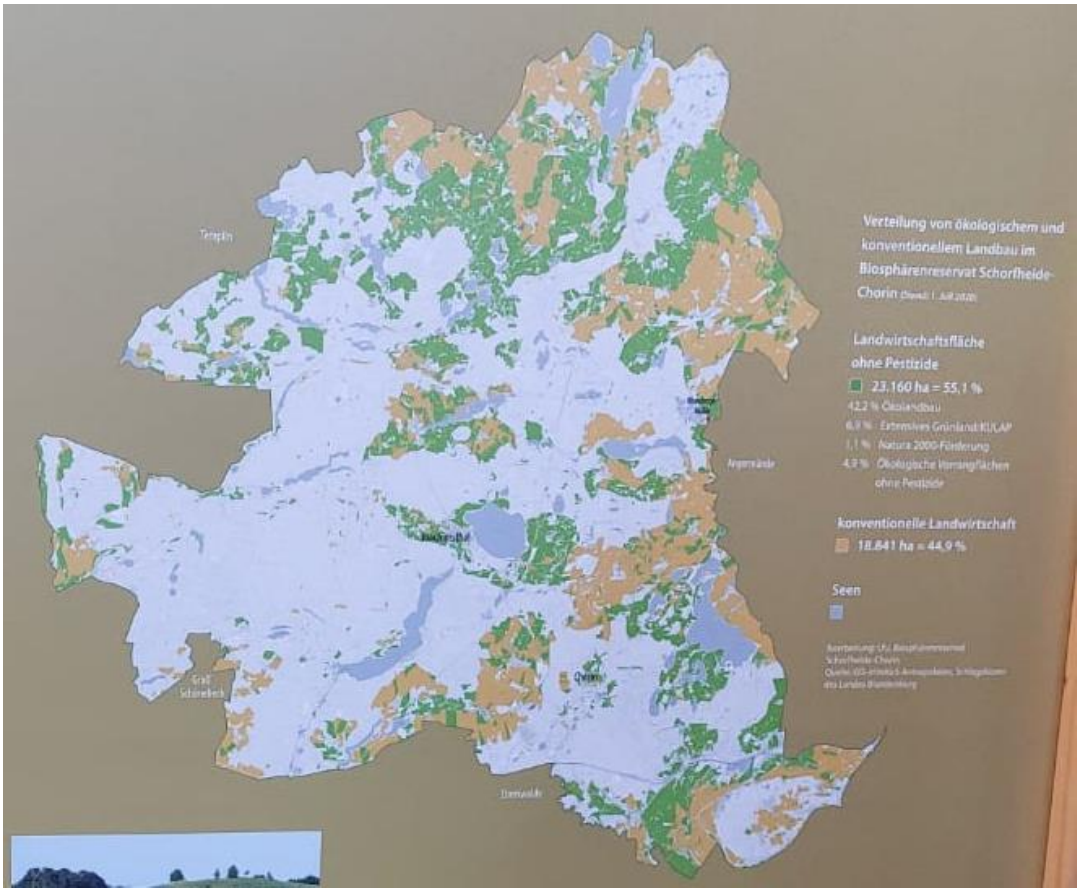


Figure 13: Map of agriculture in the reserve in which the green areas represent the parts that are farmed without pesticides and the brown parts conventional agriculture. As can be seen, the green parts tend to be in one place, and the brown parts in another.

The reserve organization itself also applies climate change adaptation measures. The biggest one addresses water. "We want to keep the water locally, the natural water supplies should be restored." The expert also mentions the micro-climate in the biosphere reserve that should be restored to provide more water. This would also help the farmers.

4.3 LINK PERCEPTIONS AND CLIMATE CHANGE ADAPTATION

In this section, the link between perceptions and climate change adaptation will be explored. First, there is a thematic qualitative part where the common themes between the perceptions and the climate adaptation measures will be discussed. Then, a more quantitative exploration of the causality between perceptions and climate change adaptation will be portrayed.

4.3.1 COMMON THEMES IN PERCEPTIONS AND ADAPTATION

As can be seen in 4.1 and 4.2, there are common themes in both climate change perceptions and climate change adaptation. The phenomenon caused by climate change that were most perceived, are also most reacted to. The phenomena can be both positive and negative.

DROUGHTS

Droughts were the most mentioned variables in both climate change perception and climate change adaptation. As Expert 1 said, "Uckermark (the county where many of the interviews were) is a disaster." It can be seen on maps earlier shown, the northeast of Germany receives some of the lowest rainfall in Germany. Out of all the farmers, only one did not explicitly mention droughts. The three farmers that did not have an FCM also brought up the dry weather, though be it, mentioning that it was natural, and the earth goes through periods of dryness sometimes.

As can be seen in the climate adaptation section, each farmer mentioned a method of soil drought adaptation. Many farmers mentioned the importance of soil health, which is endangered by the increasing number of droughts. Many different ways of adapting to these soil droughts were discovered. One of the most common methods being no-till or strip-till. This method of soil treatment leads to a decrease of water loss in the soil by not turning the lower layer of the soil on top. In a drought, it is very important that as much water as possible can be secured in the soil and does not evaporate.

Other adaptation practices also combat droughts, albeit not directly like the soil drought measures. Many of the crop adaptation practices for example are also to adapt to weather conditions with low precipitation or periods with less precipitation. More weather-appropriate crops for example. As could be seen in Figure 10, many of the crops grown in the area are winter crops or Lucerne (Alfalfa). Many farmers mentioned the need to grow more winter crops since in the winter there is more precipitation. Another farmer said, "dry or not, Lucerne grows."

Tied with the lack of rain is also the variability or the fluctuations in rain. This has also caused some farmers to take on new farming methods, such as organic farming since according to those farmers, the fluctuations in yield are lower then.

SEASONAL CHANGES

Seasonal changes were the second most mentioned variable mentioned for climate change effects, and the third most mentioned climate change adaptation technique. In the climate change effects section, most farmers rated this change as positive. In the last few years, the length of the growing season has increased. While some mentioned the change in schedule and the unplannable times as being somewhat negative, this variable was overwhelmingly positive.

This also translates to the adaptation practices. Most farmers brought up planting their crops earlier and harvesting them later. This was regarded as positive and negative as well. While it is logistically and administratively work to adjust the order and types of the crops planted, some farmers mentioned being able to plant more since the season is longer, which was regarded as positive.

HEAT

While heat was not one of the most mentioned variables, it had one of the highest centralities. It is the 4th highest in centrality and the 6th most mentioned variable. Heat seemed to be mostly a problem for farmers who also have animals. Multiple farmers mentioned that the ideal temperature for a cow is around 10 degrees. In the summer temperatures rise far above that. So, for the farmers that do experience heat as a problem, it is a difficult problem that does affect them much. When it is too hot for animals, many farmers experience a drop in production which translates to less milk being produced by cows, and fewer eggs by chickens.

As a way to combat the heat stress in animals, farmers use different techniques to relieve the animals from some of the heat. All the animal farmers mention having coolers or fans in the stables. Moreover, one farmer says to experiment with a water-cooling system to relieve the heat more. Other farmers also mention creating extra shade by for example planting trees in the pastures of the animals.

HEAVY RAIN AND WATER EROSION

While heavy rain and water erosion were high on the list of most mentioned variables in the climate change effects section, it was not high on the list with climate change adaptation practices. At the time the interviews were done, much rain had fallen in the months before and parts of fields were underwater. Not only does heavy rain destroy crops, it also causes soil erosion, wiping away parts of the soil with the overabundance of water.

Two farmers mentioned having installed a drainage system or thinking of installing a drainage system after experiencing large amounts of rain. This was, however, a small number of farmers. Key expert 1 mentions adaptation consultations for soil erosion, which as can be seen, farmers experience is mostly because of water. At the same time, there is also insurance for extreme weather, such as hail. Some farmers did not have insurance or did not consider this as an adaptation practice.

4.3.2 REGRESSION PERCEPTIONS AND ADAPTATION MEASURES

To discover if there is causality between the perceptions of climate change by the farmers, and the climate change adaptation measures employed, a regression is performed. In this regression, on the X-axis, the independent variable is put, while on the Y-axis portrays the dependent variable. In this research, the independent variable are the perceptions and the dependent variable are the adaptation practices. This is because the hypothesis is that the perceptions influence the adaptation practices.

To come to the values for the perceptions, different values that came out of the FCMs will be used. First, the number of variables on the map of each farmer will be used, then the total number of connections (arrows). Then there is the weight of the connections from climate change and in-between variables caused by climate change, shortly called: the weight of climate change. Lastly, there is the indegree from the influence of business. The value for the adaptation practices will be the number of practices the farmers mention they employ, and in some cases are planning to adopt. So, there will be 4 regressions performed.

For the regressions, 11 farmers are taken into account. One of these farmers has no map, but mentioned there to be no influence of climate change at all. Therefore, all the values for his perception will be 0. At the same time, he did have one climate change adaptation strategy.

The table below demonstrates the different values on the X-axis representing the perception. The Y-value is the number of adaptation measures. The P-value represents how far that particular part of the farmers' perceptions has a significant impact on the number of adaptation measures. Like earlier in the results, a p-value of <0.1 represents a trend, and a p-value of <0.05 represents a significant impact. As can be seen in Table 14, 3 out of the 4 regressions done have a significant P-value. The P-value for the number of variables and climate change adaptation measures was 0.02569, which is significant. The P-value for the connections was 0.03593, also significant, and the P-value for weight of climate change was 0.02998, the last significant value. The only non-significant value was that of indegree of influence on business, which has a P-value of 0.356. At the same time, the R-squared also tells something about the significance of the results, since it explains the variance that can be explained through the model. The higher the R-squared, the more significant the results. As can be seen, the first three regressions gained a relatively high R-squared while the last regression has a very low R-squared.

Table 9: P-values and R-squared of the regression performed on average number of variables, number of connections, weight of climate change and indegree of influence on climate change adaptation measures. The first three regressions report significant P-Values and average R-squared, while the last regression reports a far from significant result and a very low R-squared

X-variable	Y-variable	P-value	R-squared
The number of variables	Climate change adaptation measures	p-value: 0.02569*	Multiple R-squared: 0.4417
The number of connections	Climate change adaptation measures	p-value: 0.03593*	Multiple R-squared: 0.4028
The weight of climate change	Climate change adaptation measures	p-value: 0.02998*	Multiple R-squared: 0.4241
The indegree of influence	Climate change adaptation measures	p-value: 0.356	Multiple R-squared: 0.09519

In the Figure below, the regression lines can be seen. The first three figures are the ones that are significant. The lowest figure is the indegree on business, the one regression performed that was not found to be significant. In the first three figures, it can be seen that the dots, which represent the values of all the farmers, are roughly following the direction of the hypothesis. This was: perceptions (number of variables, connections, weight of climate change and indegree on business) have a significant impact on adaptation measures. So, for the variables, the connections, and the weight of climate change, the dots are roughly following the line of the regression. The more variables, connections, and weight, the more adaptation measures. However, in the lowest figure, the line goes in the other direction, the more influence on business, the less adaptation measures. The dots in general do not seem to follow a pattern.

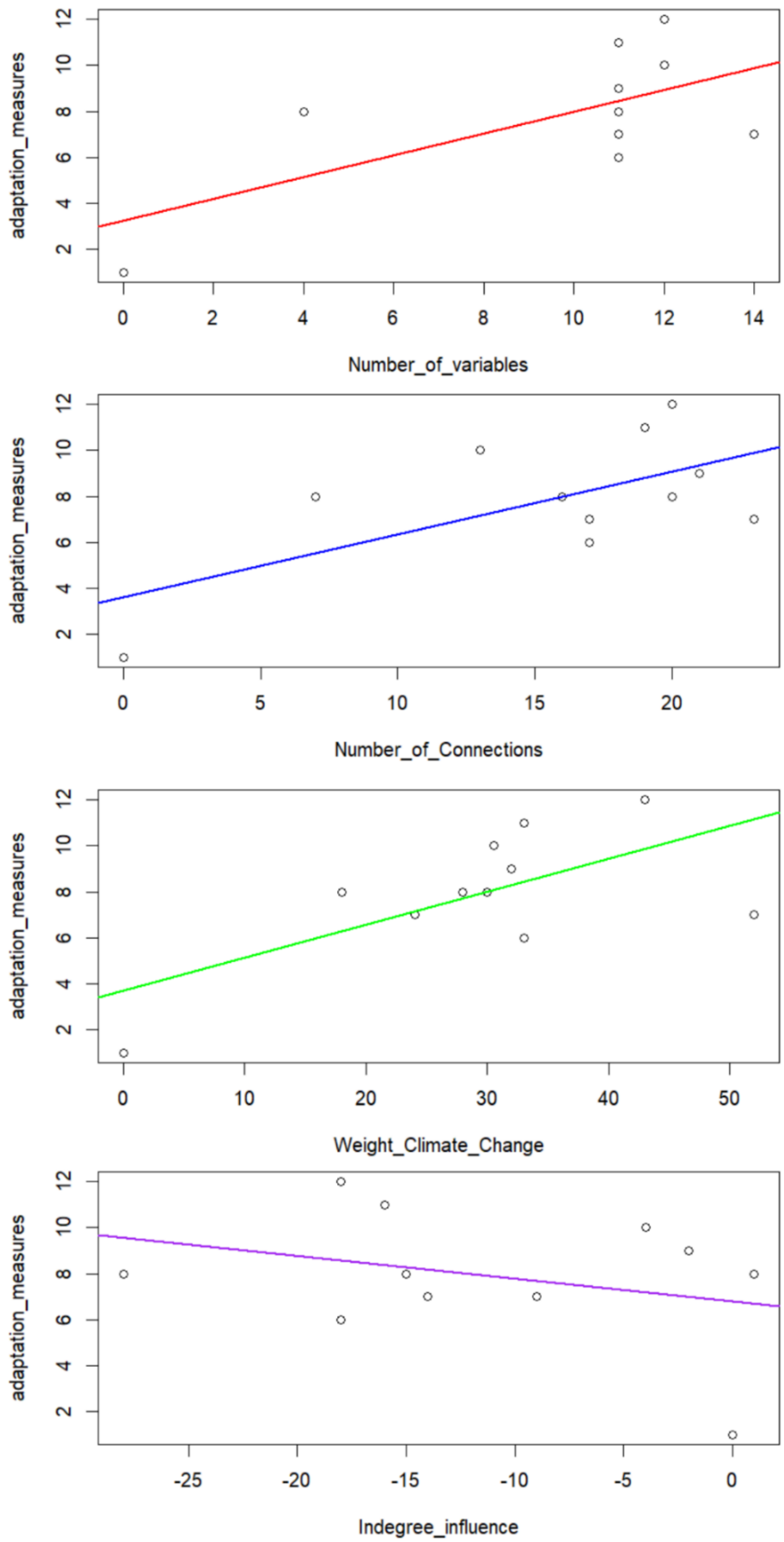


Figure 14: Regressions of perceptions of climate change against adaptation measures. The first three figures show a significant impact of variables, connections, and weight on adaptation measures. The last figure has no significant relationship.

5. DISCUSSION

This research aimed to answer the question of how perceptions of climate change among farmers influence climate change adaptation. To figure this out, first, perceptions had to be characterized and what role farm and farmer characteristics play had to be investigated. Then climate change adaptation measures had to be explored. Last, the link between perceptions and climate change adaptation was discovered. The results showed that 1, farmers have different perceptions of climate change and the influence it has on their business. Some farm and farmer characteristics have a link with perceptions. 2, all farmers adopt one way or another climate change adaptation techniques and there is a wide variety of techniques. 3, there is a link between perceptions and climate change adaptation. All of these findings are discussed in the following section.

5.1 PERCEPTIONS

FARMERS HAVE A LARGE RANGE OF PERCEPTIONS?

The first part of the results focused on farmer perceptions of climate change. As can be seen in Table 4 and Figure 11, there was a large range of different perceptions visible among the farmers. Each farmer had many different climate change phenomena that they experienced and these phenomena also differed. Many connections were made between different variables, and each farmer had a unique and personal perception.

As discussed before, there are a few factors that most farmers have in common. Common outcomes of climate change experienced by farmers are: droughts, a longer growing season, heavy rain, heat, fluctuations in precipitation, and a milder winter. The increase in droughts was the most mentioned out of all the variables. Since the study was conducted in a specific location with a small range and little difference in geographical factors, this is not surprising. However, even though there were common themes, how the farmers see the outcomes of these variables, varies greatly. While most farmers see droughts as negative, sometimes, the outcomes of those are not negative. This could include better mechanical weeding conditions. In the literature, farmers in different regions also perceive and experience droughts. Studies done by Eggers et al. (2014) and Ndamani & Watanabe, (2015) also found farmers to be highly aware of droughts. Farmers in these studies also mentioned droughts as negative as well as the main outcome of climate change in their regions.

A longer growing season was almost exclusively seen as positive. While some farmers did find some negative outcomes of the changing schedule, the longer growing season did mean for many farmers that they could have more crops grown over the year. This is an example of where farmers could see climate change as something positive, and not only bringing negative outcomes. This was also found in the study done by Menzel et al. (2006). A milder winter was also mentioned by some farmers as positive, since the harsh cold does not damage the crops. Some farmers saw it as negative though, since it can cause an increase in pests and diseases in spring. The study by Machold & Honermeier (2016) also found milder winters to be one of the main outcomes of climate change for German farmers. Heat, heavy rain and fluctuations in precipitation were solely seen as negative and damaging to crops, livestock and the business overall.

As mentioned in the literature as well, each perception is different and perceptions are highly individualistic (Smith & Sullivan, 2014; Soubry et al., 2020). Different ways of measuring perception are used in the literature, for example, some work with risk perception (Soubry et al., 2020) and others with awareness of climate change (Li et al., 2017). In this research, the term outcomes of climate change was worked with, and the influence these outcomes have on the farm. As found in multiple studies, farmers are well aware of climate change (Eggers et al., 2014), which was also found in this study. Though some farmers did not prescribe climate change to humans, or saw the changes as natural, 12 out of the 13 farmers did experience a change. This percentage is higher than the percentage found in some other studies. For example, in the study by Arbuckle et al. (2015), 31% of farmers in their study in the USA did not believe climate change was happening at all.

While most farmers saw climate change as largely negative, some farmers saw it as almost neutral or even positive. Each farmer agreed that there were both negative and positive aspects to climate change. This degree of how positive or negative it was, however, did differ greatly. This shows the difference in perceptions of climate change and its outcomes, and the wide range of different mindsets in the farmers. On the fuzzy cognitive map, the average indegree of influence on business was -12.2. While there were also positive values included, there were more negative ones. Therefore, the impact of climate change on the business is perceived as largely negative.

In the literature, farmers were largely found to not be as negative about climate change as the farmers in this study are. According to a study by Woods et al. (2017) Danish farmers largely see climate change as neutral and are not very concerned about climate change. In the USA, farmers are also not very concerned about climate change, according to Liu et al. (2013). Moreover, only a small percentage of farmers in that study believed in climate change, or that humans cause climate change. As mentioned, in this study there were also some farmers that did not believe in climate change, but they were not in the majority. The study done by Eggers et al. (2014) in Germany, showed that the farmers in more climate change affected areas did have a more negative view of climate change. This was also the finding of Jänecke et al. (2015). In their study, they reported farmers to be not only aware of climate change, but concerned about the changes this will cause on their farms. These researchers also found a correlation between geographical location and the perception of climate change. So, the findings in this research, that the farmers do seem to be largely negatively affected by climate change and therefore also perceive climate change as more negative, support the findings of Eggers et al. (2014) and Jänecke et al. (2015). A possible explanation for the fact that in the USA and Denmark, the farmers were more neutral, while in Germany, the farmers are more negative, might be attributed to the changes felt by the farmers. While in Denmark, climate change might bring new possibilities, in the Schorfheide-Chorin reserve, droughts are causing major problems for farmers.

FARM AND FARMER CHARACTERISTICS

The factors hypothesized to have a significant influence on climate change perceptions of farmers in Germany include farm and farmer characteristics. As discussed in the theoretical framework, according to the literature, several factors, such as age, gender, farm size and management style (organic or not) are assumed to have a significant impact.

As can be seen in Table 6, none of the characteristics were found to have a significant impact on the perceptions, which means none had a P-value of less than 0.05. However, in some cases, there was a link found. This means that there were cases where the P-value was less than 0.1. This was the case for the Average weight of climate change between the organic and non-organic groups, and the indegree influence on business between the younger and older farmers. This means that a link can be made between whether a farmer is organic or not and how much they experience climate change. The organic farmers gave on average a higher weight to the changes they experience in the weather, meaning they experienced more outcomes from climate change and have a broader perception of the phenomenon of climate change itself. This finding is in agreement with the findings of Jänecke et al. (2015) where it was concluded that organic farmers tend to have a broad view of climate change. A new finding of this study was however that the interviewed organic farmers did not experience a greater influence of those changes than non-organic farmers. This might be the case because according to Scialabba & Müller-Lindenlauf (2010) it was found that organic farming can decrease the effects experienced by climate change. So, while organic farmers do experience climate change, and are aware of it, they might experience fewer negative outcomes from it because of their way of farming.

This study found a connection between age and climate change perception, but it was not the connection that was found in the literature. While Eggers et al. (2014) found no connection to age, Jänecke et al. (2015) as well as Wheeler et al. (2013), and Baiardi and Morana (2021) did. However, they found that younger farmers are more concerned with climate change than older farmers. They speculated that this might be the case because younger farmers might look into the future more, and are therefore more concerned about long-term trends. In this study, the age of the farmer was found to have a link with the indegree of influence on business. This means that the older farmers on average experienced more negative outcomes of climate change than younger farmers. The finding that older farmers experience more negative consequences of climate change could be attributed to the fact that older farmers have experienced more climate change firsthand. They have seen what the climate was like 30 years ago. They have experienced the factors that they describe, and have a larger frame of reference to compare the climate of today to the climate of the past. Furthermore, this study found no connection with farm size even though the farm sizes of the farmers in the study varied greatly, while the study by Li et al. (2017) did find a positive correlation between climate change awareness and farm size. Also in the study of Eggers et al. (2014), it was found that farmers with larger farms tended to have a more negative perception of climate change.

So to answer the first sub-question: What characterizes farmer's perceptions of climate change and how do farm(er) characteristics influence them? What characterizes farmer perceptions is on one hand the high degree of variability in the degree of negative influence of climate change among farmers. On the other hand, there are common themes found among farmers, for example, the prevalence of droughts, and its negative impact on farmers. None of the farm(er) characteristics have a significant impact on perceptions. However, trends can be seen in the degree of climate change experienced by organic farmers, which is higher than non-organic farmers. Older farmers experience more negative impacts of climate change than younger farmers.

5.2 CLIMATE CHANGE ADAPTATION

The second part of this research focused on climate change adaptation. Farmers were asked what kind of methods they employ in response to the outcomes of climate change. Even though there are many different measures, there are some trends to be seen. As mentioned in the perceptions, drought was the most experienced outcome of climate change. The response to this was largely to adopt drought-mitigating measures of climate change adaptation. While every single farmer adopted drought mitigation techniques, the type of measure still differed. This can partly be attributed to the diversity of farm management styles. Some farmers in the sample were solely arable farmers, while some also have animals. The adaptation measures employed differ per farm type, with for example heat adaptation much more common in farmers with livestock. After drought adaptation, crop adaptation was the most popular climate change adaptation measure. Many farmers mentioned trying out new crops or crop species. There were some ideas of growing soy or getting water buffalos. This shows the openness of the farmers to new products and their willingness to adapt and make big changes.

Other popular adaptation measures include seasonal changes adaptation, heat adaptation and altering farming techniques. Seasonal change adaptation was mostly about sowing and harvesting earlier and later. Heat adaptation was mostly employed by animal farmers, which included putting coolers in stables or shade in pastures. The last measure, altering farming techniques, were larger, farm-wide techniques. This includes for example farmers going organic to spread the risk of climate change. Moreover, this category included many future plans. Some farmers imagined trying out completely different farming methods, such as agroforestry or regenerative farming. This shows the farmers are not only adapting parts of farming, but their entire way of running the farm. This shows a high willingness to change as well as a high need.

There are many categories of climate change adaptation measures, with even more different techniques within these categories (Table 7). All together, 26 different climate change adaptation techniques were used over 13 farmers, with an average of 8 techniques per farmer. This means that farmers are very aware of the risk of climate change, or weather events, and are willing and able to act upon it, by using different adaptation measures tailored to different climatic events. This high percentage of 100% of the farmers that have adopted climate change adaptation measures is unseen in the literature. For example, in the study of Li et al. (2017), 50% of farmers had adopted adaptation measures. In the study of Arbuckle et al. (2015) 62% of farmers agreed that farmers should take steps to protect their land from outcomes of climate change, such as increased precipitation.

In the literature, different adaptation measures of German farmers were also found. In the studies done by Eggers et al. (2014) and Dang et al. (2019), mostly crop adaptation measures were found. These include trying out new crops and adapting crop varieties. While these methods were also common in this research, it was not the most common one. This can be attributed to the fact that droughts were widely experienced and keeping moisture in the soil was the biggest priority for the farmers in the Schorfheide-Chorin reserve. The study done by Reyer et al. (2011) did find drought adapting techniques to be the most used one in Brandenburg. This includes reduced tilling, and improved soil water infiltration. One of these measures mentioned is to keep the soil always covered. This was a widely mentioned adaptation technique in both the study done by Reyer et al. and in this study. This shows again how there are big regional differences in climate change adaptation, even within the country. In the research done by Li et al. (2017) water-saving soil techniques were also the most common adaptation method. An interesting finding was that the literature does mention irrigation as a large climate change adaptation finding, but in this research, irrigation was rarely used. This was largely because of different factors holding the farmers back, such as water rights, logistics, or finances. Not only were some of these factors holding back irrigation, also other climate change adaptation measures were held back by certain barriers.

BARRIERS

Four categories of mostly political factors were mentioned by the farmers, as can be found in Table 8. The fact that almost every single farmer mentioned these means that politics are on the farmers' minds, and are heavily intertwined with climate change adaptation. The four categories that were found were: subsidies, bureaucracy/ too many rules, lack of knowledge of policy-makers, and policy-making being too centralized/gap. Since politics has a role to play in the incentivisation and support of climate change adaptation measures, this disconnect is a barrier for many farmers to adopt adaptation measures.

The first barrier was subsidies. Climate change adaptation costs money, and not all farmers have the finances to adopt these. Some farmers mentioned specifically that they do not have money to implement adaptation measures, while they would be willing to implement more. According to Mitter et al. (2019), the high cost of certain adaptation practices is holding farmers back. The costs associated with adaptation are high, but necessary. Another obstacle to the farmers in the study done by Mitter et al. was untargeted subsidies. So sometimes, the subsidies are there, but they are not targeted well enough to farmers who need them, or they are difficult to receive.

The second barrier is the lack of knowledge of policy-makers. Since farmers have the feeling that many policy-makers do not have the knowledge to advise them on which adaptation measures to adopt, they will not listen to them, even if there are subsidies available. Farmers feel left out of the decision-making process, which can also make them adverse to any consultation about climate change adaptation. In the study done by Rust et al. (2021), it was found that farmers are increasingly distrusting of governmental institutions and academics. They found that farmers mostly trust other farmers. Since they feel not represented by politics, this might also be because they value their level of expertise less than their own or that of other farmers. The findings by Arbuckle et al. (2015) support this. They found that farmers have much higher trust in agricultural groups and institutions than in governmental ones.

The third barrier is bureaucracy. This is the logistics it takes to adopt an adaptation measure. Some farmers mentioned wanting irrigation, but the logistical burden would be too large. With different crops also come different administrative duties. In the research done by Mitter et al. (2019), many farmers also named the administrative burden as an obstacle to climate change adaptation. Farmers mentioned rules being inflexible, and administrative barriers.

The fourth barrier was that agricultural policy-making is too centralized, which causes a gap between the farmers and the governmental institutions. Farmers expressed that they feel unheard by policy-makers in the provincial or country-wide ministries. Measures are not local enough, and might not apply to specific farm conditions. As mentioned by Rust et al. (2021), farmers have a larger growing distrust for governmental institutions, which are usually centralized. They found that government employees are too far away from the farmers, while the knowledge of their fellow farmers is more local, and more applied to their situation. Another study by Dang et al. (2019) found that trust in the government is also influenced by earlier decisions that have not been in favour of the farmers. Some farmers in this study also voiced concern about policy decisions made by government officials that were in their view not in their best interest. This barrier was also explored during the interviews with the experts. While none of the farmers mentioned having any contact with the ministry, the ministry does have programs for climate change adaptation. Expert 1 also has the technical knowledge about farming and the climatic situation in the region. However, this expert was further away from the farmers, both in location and mindset. The ministry does not reach out to the farmers, the initiative has to come from the farmers, which was largely not happening. The local expert seemed more in favour with the farmers, and more knowledgeable about the specific conditions of the reserve. Expert 2 had contact with the farmers and reaches out to farmers for certain projects. While both experts were knowledgeable, the gap between the farmers and the experts were different because of the difference in the locality of the experts.

All in all, farmers are knowledgeable about climate change adaptation, and what works for their farm in different conditions, such as droughts and extreme weather events. They host a large number of different adaptation techniques that are suited to their farm, and its conditions. Adaptation measures vary from drought adaptation, to crop adaptation to heat adaptation, to heavy rain adaptation. Most farmers have adaptation measures for different weather and climatic events. But there are factors holding them back, including, subsidies that are misplaced and not in place at all, a perceived lack of knowledge among policy-makers, too much bureaucracy and too strict rules, and a too centralized setting in policy-making that is not specific enough to the local context.

5.3 THE INFLUENCE OF PERCEPTIONS ON CLIMATE CHANGE ADAPTATION

It is clear from this research that perceptions do influence climate change adaptation. When a farmer has a more complex perception of climate change, they are likely to adopt more climate change adaptation practices. Furthermore, the themes found in the perceptions are also found in the adaptation practices, making the two concepts not only linked in causality, but also by content. This result is not only the case in Brandenburg, Germany, but also in other parts of the world. While perceptions might not be the only or even the most important influencer of climate change adaptation, this research, as well as other research, has shown that it does have some impact on adaptation and this impact should not be ignored.

As can be seen in the results of 4.3.1, the themes in the perceptions and climate change adaptation are similar. The number one outcome of climate change was droughts, at the same time, soil drought adaptation was the most used adaptation method. Other themes that matched were seasonal changes and seasonal changes adaptation and heat and heat adaptation. This is already the first clue to perceptions and adaptation methods having a link. Since the most common themes in perceptions were droughts, heat and seasonal changes, it suggests that these are also the most common themes in adaptation since, the event causes the reaction. Common themes do not indicate causation, only correlation. To test whether there is causation, regressions were performed.

As can be seen in the results section 4.3.2, 3 out of 4 regression analyses were significant, and showed therefore a causal relationship between perceptions and climate change adaptation. The causal relationships were between the number of variables, the number of connections and the weight of climate change with the number of climate change adaptation measures. In particular, the most outcomes, as well as the most connections and largest weight of climate change, are perceived by farmers with higher numbers of adaptation practices. This confirms the hypothesis posed in this research. Only the indegree of influence on business was not significant, which goes against the hypothesis stated in the theory. This means climate change's influence is not perceived negatively by farmers who adapt the most. This could be the case because as mentioned before, the younger farmers see climate change as less negative, while the older farmers see it as more negative. It could be that the younger farmers are more strongly thinking about the future and therefore adopting more adaptation measures. In the literature, it is also found that younger farmers tend to be more eco-focused (Jänecke et al., 2015). Another possible explanation is that since the farmers adopted these measures, the influence of climate change on the business went down. For example, a farmer perceives drought having increased, but since they adapted soil water-saving techniques, the influence of droughts on the business has decreased. One farmer mentioned storms having increased. However, since this farmer now has a wind turbine, the influence of storms is perceived more positive than negative. Nevertheless, perceptions have been found to influence the adoption of adaptation measures, which was also a finding of several studies in different parts of the world.

Li et al. (2017) found that there is a causal relationship between perceptions of climate change and climate change adaptation. They saw that farmers who have a heightened belief in climate change also were more aware of it. In turn, they also found that climate change awareness was a driver of adaptation. However, they found that it was not the main one, it is more likely that it goes hand in hand with other drivers, such as financial motives. Wheeler et al. (2013) found that belief in climate change is positively correlated with certain adaptation measures, such as implementing new crop types and adopting more efficient irrigation infrastructure. They also found there to be a relationship in the other direction. The belief in climate change was also heightened by the increase in climate change adaptation strategies. However, this study also found beliefs to not be the main driver behind adaptation. They also found financial capital to be influencing adaptation. As mentioned in the barriers of climate change adaptation, subsidies were also an issue in this research. Teixeira et al. (2018) also found a more complex perception of ecosystem services, which is related to climate change perception, to be influencing the diversity of the farming system. As mentioned before, a diverse farm system with for example more crop types, is an adaptation strategy. In the study by Arbuckle et al. (2015), it was found that with a larger perceived risk of climate change, farmers are significantly more likely to support adaptation measures.

These studies show that all over the world (Germany, Hungary, Australia, Brazil and the USA) farmer perceptions of climate change do have an influence on climate change adaptation. While these studies alone may be specific for one region, these studies together do indicate a larger pattern. The circumstances in the different studies are different, but still, perceptions influence adaptation. While the degree of the impact may differ, the impact is there. Therefore, we can generalize this picture more and more to other regions of the world as well.

5.4 REFLECTION UPON METHODS

The usage of Fuzzy Cognitive Maps gave this research a clear picture of perceptions, a way to visualize perceptions, as well a way to operationalize them. This did not only help in answering sub-question 1. but it also gave the necessary numerical values, such as the number of variables, number of connections, weight of climate change, and indegree of influence on business. These were needed to do the regression, as well as the statistical analysis of the characteristic groups. The statistics tests themselves was a suitable method for getting the quantitative information necessary to state causality, which was the main goal of the research. The regression worked well with the link between perceptions and adaptation practices, as could be seen by the significance values. The thematic content analysis also worked well since similarities between the themes in perceptions and in climate adaptation measures could be brought to light.

However, it can be questioned whether the quantitative methods were performed on a group that was large enough. The Wilcoxon tests also show this. There was little significance, if any at all. This might be because the groups truly do not have a difference, but outliers could already make a large difference and make a whole group insignificant. Since there were only five farmers per group, each farmer had a big influence on the group, which made the data very sensitive to outliers. However, with only around 100 farmers in and around the reserve, the sample size of 13 farmers represents a significant proportion. This sample effectively characterizes the farmers under the specific conditions of the reserve.

5.5 RECOMMENDATIONS

From the results of this research, some recommendations can be made. As for the ministry and the organization in the reserve, a more hands-on and less centralized approach could benefit the farmers. There was clear criticism from the local farmers about the gap between farmers and the government that is becoming bigger. Farmers need more representation in local governments as well as nationwide governments. It was found during the interviews, as well as in other articles (Rust et al. 2021; Dang et al. 2019), that farmers do not have high trust in the government. Incorporating more farmers or agricultural specialists in the government could mend this distrust.

The perception of farmers is invaluable in finding the right measures to cope with the effects of climate change on their businesses and livelihoods. Therefore, this study can be of great use to policymakers and scientists working on climate adaptation in agriculture. Farmers are not helpless standing by while climate change is happening. They are actively preventing food losses and the loss of their own livelihood.

However, there are still barriers that are holding them back. First of all, those barriers should be addressed. Farmers should have more tools to deal with climate change as well as receive more support in coping with it. They should not be worked against, which is now the case by for example the ever-increasing bureaucracy that is presenting itself. Moreover, farmers should be more central in the decision-making process. As can be seen in many studies, they are knowledgeable about their own farming techniques. Some farmers do not see the influence of climate change and could benefit from a more hands-on and direct approach from policymakers. As discussed by Li et al. (2017), information about the damages of climate change should be made more available, and farmer engagement in adaptation practices should be more stimulated.

6. CONCLUSION

This research intended to investigate perceptions as well as climate change adaptation measures, and the impact of the former on the latter. To gain insight into this relationship, first perceptions and what influences those were looked at. It became clear that farm characteristics do not have a large impact on perceptions. Only the farm management style has an impact on the complexity of the perceptions about the outcomes of climate change, and the age of the farmer has an impact on how negatively a farmer experiences climate change. The perceptions themselves were very broad with many different variables and outcomes of climate change experienced by different farmers, but some themes, like droughts being dominant were found. Other than droughts, a longer growing season, heavy rain and heat were also largely experienced by farmers. These themes were also found in climate change adaptation, almost following the same order in the times mentioned in perceptions as in climate change adaptation. Since droughts are the most experienced outcome of climate change, most adaptation measures are to adapt to those droughts. Each farmer had many ways to adapt to the changing climate, offering various different adaptation strategies, with eight different adaptation techniques on average per farmer. This shows that farmers are largely able and willing to adapt to the challenges climate change brings. In the themes aligning, a link can be seen. Through performing regressions, direct causality was also found. Three aspects of perceptions were found to significantly impact the number of climate change adaptation measures. The number of variables, the number of connections and the weight of climate change were all significant. Only the impact of the outcomes of climate change on the farm was not. This could be because farmers have several adaptation strategies and might therefore experience climate change as less negative. Some farmers are sceptical and there are barriers still standing in the way of adaptation, which includes many political and economic challenges. A more personalized policy-making should be done, and farmers should be better represented. More research in other areas of the world find the same, making these results globally important.

7. SOURCES

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APPENDICES

APPENDIX 1: INTERVIEW GUIDELINES

Interview guidelines

Europe-land project

1. Opening

1.1 Introduction. We are Daniel, Jerry, Florian and Yanaika, researchers from IAMO. We are doing research on climate change and agriculture.

1.2 Goals. The goal of our research

1.3 Anonymity. Everything you say will be anonymous. This is a safe space and you can express all of your opinions without judgement, and there is no wrong opinion. You are valuable to our research and we appreciate you joining immensely.

1.4 Recording consent. Do you agree with us recording this interview so we can listen to it later to check we haven't forgotten anything? It is no issue if you do not want the interview to be recorded. If there is no recording possible, we will make notes.

2. Basic information

2.1 What is your name, age, gender, (education)

2.2 What are major crops and products on your farm?

2.3 What is the size of your farm?

2.4 What are land-use types on your farm? Is it mostly cropland, do you also have pastures or dedicated forest land?

3. Fuzzy Cognitive Map construction

3.1 Explanation of the fuzzy cognitive map with an example unrelated to this research. An FCM is a sort of mind map in which different variables interact and have influence on each other.

3.2 Questions for the construction of the map:

Q1: What changes in the climate have you experienced in the last 10/20 years? (prompt: temperature changes, precipitation changes, biodiversity loss, pests and diseases, soil quality)

Q2 How do the mentioned climate change factors influence the functioning of the farm? For example, is there an influence on animal productivity, biodiversity, crop productivity, animal production, and soil quality? Are there other important factors influenced by climate change?

Q3 How do these influence each other? For instance, does biodiversity loss impact any of the other factors?

Q4 Are there also positive impacts on your farm from climate change? For example, new crop types available, or a more convenient planting/harvesting schedule?

Q5 What is the influence of changes in the farming system on labor and input use?

Q6: How do you respond to these changes? Which adaptive management practices have you taken? (prompt: organic farming, adapted crop types, heat resilience) What is the influence of those measures on the factors present in the map?

Q7 Add a step to weight all the connections between the different factors from 0 to 5 (positive or negative)

Q8 Add a final step to ask farmers whether there are still factors/connections missing and whether the map represents their vision. If this is not the case yet, additional amendments can be made until the map reflects the farmers' perception.

4. Closing

4.1 Express gratitude. Thank you for participating in our research, your contribution is much appreciated and valued.

4.2 Offer insight in final product. Would you like to see the final product?

APPENDIX 2: EXPERT INTERVIEW QUESTIONS

Opening questions:

Introduction

Research Goals

Anonymity

Recording consent

Main questions:

What effects of climate change have you experienced? What is the situation in the Schorfheide?

What makes farming in the reserve/ Brandenburg different from farming in different places? Are there regulations in place?

How do you think climate change has affected farmers in the region?
Positive changes?

Which aspects of agriculture are affected?

Which type of farmer is the most commonly affected?

How have farmers reacted to these changes? Have they taken adaptation measures?
What is the most important/effective adaptation measure?

What climate adaptation tools are available to farmers?
How does the ministry/ reserve help/incentive farmers to adopt climate change adaptation tools?

How do these measures affect the problems experienced from climate change by farmers?

Closing questions:

Do you have anything to add?
Thank you for participating
Offer insight in the final product

APPENDIX 3: SOCIAL MAP OF ALL FARMERS

In the figure below, the entire social map of all farmers with all variables can be found.

Social ma	Climate c	Droughts	Longer gr	Heavy rai	Heat	Milder wi	Water ero	Uncertain	Higher te	Fluctuatio	Unplanna	Poor con
Climate c	0,00	0,60	0,46	0,20	0,30	0,20	0,00	0,10	0,18	0,18	0,12	0,12
Droughts	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08
Longer gr	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,00	0,00	0,00	0,06	0,00
Heavy rai	0,00	0,00	0,00	0,00	0,00	0,00	0,26	0,00	0,00	0,00	0,00	0,00
Heat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Milder wi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Water ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Uncertain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00
Fluctuatio	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Unplanna	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Poor con	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Yield dec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Stress (A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More pre	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Warmer i	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Extreme v	0,00	0,09	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Political p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More we	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Little wat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Incline wa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier sp	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher co	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher ea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Income di	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier dr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lack of p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hot grou	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Microorg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heavy soi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Better m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less freq	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Storms m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Drought	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfor	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Societal p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Parasites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Weather	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Winter m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Plant dis	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Longer p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Influence	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Social ma	Yield dec	Performa	Stress (A	More pre	Less fros	Warmer i	Extreme v	Wind ero	Political p	More we	Higher te	Little wat
Climate c	0,08	0,00	0,06	0,14	0,14	0,08	0,24	0,00	0,10	0,06	0,10	0,00
Droughts	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,00	0,08
Longer gr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heavy rai	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat	0,06	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Milder wi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00
Water ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Uncertain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00
Fluctuatio	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Unplanna	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Poor con	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Yield dec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Stress (A	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More pre	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Warmer i	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Extreme v	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Political p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More we	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Little wat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Incline wa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier sp	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher co	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher ea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Income di	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier dr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lack of p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hot grou	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Microorg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heavy soi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Better m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less freq	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Storms m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00
Drought	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfor	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Societal p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Parasites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Weather	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Winter m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Plant dis	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Longer p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Influence	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Social ma	Incline wa	Less fros	Earlier sp	Higher co	Higher ea	Income di	Earlier dr	Lack of p	Hot grou	Microorg	Heavy soi	Better m
Climate c	0,00	0,04	0,00	0,10	0,08	0,00	0,00	0,00	0,08	0,00	0,00	0,00
Droughts	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,08	0,02
Longer gr	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heavy rai	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Milder wi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00
Water ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Uncertain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Fluctuatio	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00
Unplanna	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Poor con	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Yield dec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Stress (A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More pre	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Warmer i	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Extreme v	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Political p	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00
More we	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Little wat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Incline wa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier sp	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher co	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher ea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Income di	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier dr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lack of p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hot grou	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00
Microorg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heavy soi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Better m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Less freq	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Storms m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Drought	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfor	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Societal p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Parasites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Weather	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Winter m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Plant dis	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Longer p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Influence	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Social ma	Less freq	Storms m	Drought	Transfor	Societal p	Parasites	Weather	Winter m	Plant dis	Longer p	Influence
Climate c	0,02	0,08	0,00	0,00	0,08	0,00	0,04	0,00	0,00	0,10	0,00
Droughts	0,00	0,00	0,08	0,10	0,00	0,00	0,00	0,06	0,08	0,00	-0,62
Longer gr	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,22
Heavy rai	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,22
Heat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,16
Milder wi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Water ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,24
Uncertain	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,10
Fluctuatio	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,26
Unplanna	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,12
Poor con	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,24
Yield dec	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Performa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,04
Stress (A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,10
More pre	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,04
Warmer i	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Extreme v	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wind ero	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02
Political p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
More we	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Higher te	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06
Little wat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Incline wa	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Less fros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04
Earlier sp	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04
Higher co	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Higher ea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,12
Income di	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Earlier dr	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lack of p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,04
Hot grou	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Microorg	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Heavy soi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Better m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Less freq	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06
Storms m	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Drought	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfor	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,10
Societal p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Parasites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02
Weather	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00
Winter m	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Plant dis	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Longer p	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Influence	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

ADJUSTED SOCIAL MAP

Social map	Climate ch	Droughts	Longer gro	Heavy rain	Heat	Milder wint	Water eros	Higher tem	Fluctuation	Unplannab	Poor condi	Yield decli	Performan	Stress (Ani	More preci	Less frost	Warmer in	Higher tem	Incline wat	Earlier spri	Higher earn	Hot ground	Microorgan	Heavy soil	Drought str	Transform	Winter mor	Plant disea	Longer per	Influence on
Climate ch	0,00	0,60	0,46	0,20	0,30	0,20	0,00	0,18	0,18	0,12	0,12	0,08	0,00	0,06	0,14	0,14	0,08	0,10	0,00	0,00	0,08	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,10	0,00
Droughts	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,08	0,08	0,08	0,10	0,06	0,08	0,00	-0,62
Longer gro	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,22
Heavy rain	0,00	0,00	0,00	0,00	0,00	0,00	0,26	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,22
Heat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,16
Milder wint	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Water eros	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,24
Higher tem	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,10
Fluctuation	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,26
Unplannab	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,12
Poor condi	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,24
Yield declin	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Performanc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,04
Stress (Ani	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,10
More precip	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Less frost	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,04
Warmer in	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Higher tem	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06
Incline wat	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Earlier spri	0,00	0,00	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04
Higher earn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,12
Hot ground	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Microorgar	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,06
Heavy soil	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Drought str	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transform	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,10
Winter mor	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	-0,08
Plant disea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,08
Longer per	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
Influence c	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

APPENDIX 4: ORIGINAL LIST OF VARIABLES (IN GERMAN)

Variables deutsch	times mentioned
Klimawandel	10
Einfluss auf der betrieb	10
Trockenheiten	9
längere vegetationszeit	7
Stark regen	6
milderer winter	5
wasser erosion	5
hitze	4
höheren temperaturen	3
schwankungen in niederschlag	3
unplanbar	3
schlechte Bedingungen Pflanzenwachstum	3
getreide sinken	3
extreme wetterereignisse	3
Unsicherheit	2
leistung depression	2
stress (tier)	2
mehr niederschlag im winter	2
weniger frost	2
im sommer warmer	2
wind erosion	2
politische druck	2
mehr unkraut	2
trockenstress in pflanzen	2

Höheren temps blute phase	2
wenig wasser verfugbar	1
steigung wasserverbrauch	1
weniger frost ohne schnee	1
früherer Frühling	1
höhere co2	1
höhere ertragsvolatilität	1
einkommensdiversifizierung	1
fruher trocken	1
fehlt schutz von schnee	1
heiße bodenboberflache	1
micro-organismen sterben	1
schwere bodenbearbeitung	1
besser striegeln in trocken	1
seltener längere naß phasen	1
sturme heufiger	1
transformationsprozessen	1
geselltschaftliche druck	1
parasieten (fliegende insekten)	1
wetterereignisse sind länger	1
winter mehr trocken	1
krankheiten in pflanzen	1
längere periode mit regen	1
Ertragsausfälle (merge with höhere ertragsvolatilität)	
keine reserven für pflanzen (merge with trockenstress pflanzen)	
pflanzentot (merged with getreide sinken)	
intensivere Witterungsphase (merge extreme wetterereignisse)	
erosion (merged with wasser erosion	
schlechter verteilte niederschlag (merge schwankungen in niederschlag)	
angst in der geselltschaft by green party (merge with politische druck)	
warmer in winter (merge with mildere winter)	
unterschiedliche niederschlag (merge schwankungen in niederschlag)	
weniger ausgeprägte Jahreszeiten (merge with unplanbar)	
weniger winter (merge with mildere winter)	
großere extremen in regen (merge with stark regen)	
längere trocken phasen (merge with trockenheiten)	
ackerbauliche termine anders (merge with unplanbar)	
extreme niederschlag (merge with stark regen)	
mehr zu tun für hochwertig futter (merge with schlechte bedingungen pflanzenwachstum)	
längere periode ohne regen (merge with trockenheiten)	
trocken + hitze (merge with trockenheit)	

APPENDIX 5: COMPLETE LIST OF CLIMATE CHANGE ADAPTATION MEASURES

Adaptation practices	Mentioned	Related/ more specific
Keep the soil covered	8	Intercrops/ in-between crops
		Increase ground cover
		Mulch
		stubble cultivation
		Water-saving soil preparation
Change harvest and planting times	7	Earlier planting time
		Later harvest
		Earlier harvest when it is dry
Trying new crops	6	Soy (with irrigation)
		Drought-resistent crops
		Hemp
More weather appropriate crops	6	Corn
		Alfalfa
		Switching to more winter plants
No till or strip till	6	Stop plowing
		Strip-till
Adapt crop rotation	5	
Trying new species	5	Trying climate-adapted species
		Drought-resistent species
Diversifying/ Spread the risk	5	More different crops
		More different species
Cooling in stables	4	Fans
		Water-cooling
Considering new farming types	3	Agroforestry
		Regenerative
Planting Hedges	3	
Shade (for animals)	2	
Switching to organic	2	Less dependent on water
Trying irrigation	2	
Renewable energies	2	Solar
		Wind power
Efficiently using rain	2	
use the extra co2 in air for hummus build-up	2	

Direct seeding	1	
Prevent soil compaction	1	
Water saving weeding	1	
Fertilizing with more water intake	1	
Adapt grazing rotation	1	
Buying new equipment	1	
enlarge surface area	1	
give up parts of the business	1	
Using liquid nitrogen fertilizer	1	

APPENDIX 6: GROUPS OF VARIABLES

	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8	Group9	Group10
Group Name	Precipitation	Temperature	Weather ever	Economy	Seasons	Conditions	Society	Disease	Climate chang	influence on bus
inner color	Yellow	Green	Blue	BlueViolet	Bittersweet	BurntOrange	Brown	Mahogany	Gray35 Gray4	Aquamarine
border color	Black	Black	Black	Black	Black	Black	Black	Black	Black	Black
shape	ellipse	ellipse	ellipse	ellipse	box	ellipse	ellipse	ellipse	ellipse	ellipse
label color										
boundary width										
Number of group members	12	12	4	4	4	3	4	3	1	1
Members	Droughts	Heat	Extreme weat	Yield decline	Longer growir	Poor conditio	Political press	Parasites (flyi	Climate chang	influence on bus
	Heavy rain	milder winter	wind erosion	Higher earnin	Insecurity	Heavy soil cul	Higher co2	Plant diseases		
	Water erosion	Higher tempe	Storms more	Income divers	unplannable	Better mecha	Transformatic	More weeds		
	Fluctuations in precipitation	Performance	Weather ever		Earlier spring		Societal pressure			
	More precipitation in winter	Stress (animal)								
	Little water available	Less frost								
	Incline water consumption	Warmer in summer								
	Earlier dry	Higher temperatures flowering phase								
	Less frequent longer wet phases	Less frost without snow								
	Drought stress in plants	Lack of protection from snow								
	Winter more dry	Hot ground surface								
	Longer periods with rain	Microorganisms die								

APPENDIX 7: FULL LIST OF VARIABLES WITH CENTRALITY

Density	
0,045269353	
Total Nr. Factors	**Total Nr. Connections**
47	100

Concepts	**Outdegree**	**Indegree**	**Centrality**	**Number of times mentioned**
Climate change	4,08	0,00	4,08	10
Influence on the business	0,00	3,66	3,66	10
Droughts	1,43	0,75	2,18	9
Longer growing season	0,45	0,46	0,91	7
Heavy rain	0,52	0,36	0,88	6
Heat	0,38	0,30	0,68	5
Fluctuations in precipitation	0,40	0,18	0,58	3
Water erosion	0,24	0,26	0,50	4

Milder winter	0,12	0,35	0,47	5
Poor conditions plant growth	0,24	0,20	0,44	3
Higher temperatures	0,20	0,18	0,38	3
Extreme weather events	0,13	0,24	0,37	2
Stress (Animal)	0,18	0,14	0,32	2
Unplannable	0,12	0,18	0,30	3
Higher earnings volatility	0,12	0,16	0,28	1
Warmer in summer	0,16	0,12	0,28	2
Yield decline	0,08	0,18	0,26	3
Microorganisms die	0,06	0,16	0,22	1
Winter more dry	0,16	0,06	0,22	1
Transformation processes	0,10	0,10	0,20	1
Performance depression	0,04	0,16	0,20	2
Less frost	0,04	0,14	0,18	2
Earlier spring	0,10	0,06	0,16	1
Drought stress in plants	0,00	0,16	0,16	1
Longer periods with rain	0,02	0,14	0,16	1
More precipitation in winter	0,02	0,14	0,16	2
Higher temperatures flowering phase	0,06	0,10	0,16	2
Incline water consumption	0,08	0,08	0,16	1
Hot ground surface	0,08	0,08	0,16	1
Heavy soil cultivation	0,08	0,08	0,16	1
Plant diseases	0,08	0,08	0,16	1
Weather events are longer	0,10	0,04	0,14	1
Political pressure	0,04	0,10	0,14	2
More weeds	0,06	0,08	0,14	2
Little water available	0,06	0,08	0,14	2
Wind erosion	0,02	0,11	0,13	2
Higher co2	0,02	0,10	0,12	1
Storms more frequent	0,04	0,08	0,12	1
Uncertainty	0,00	0,10	0,10	3
Earlier dry	0,00	0,08	0,08	1
Societal pressure	0,00	0,08	0,08	1
Less frost without snow	0,04	0,04	0,08	1
Lack of protection from snow	0,04	0,04	0,08	1
Less frequent longer wet phases	0,06	0,02	0,08	1
Income diversification	0,00	0,04	0,04	1
Better mechanical weeding in dry conditions	0,02	0,02	0,04	1
Parasites (flying insects)	0,02	0,02	0,04	1