The resilience of the farming system in Reusel regarding drought

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The resilience of the farming system in Reusel regarding drought

Master Thesis Water Systems and Global Change Group in partial fulfilment of the degree of Master of Science in the master program Climate Studies at Wageningen University, the Netherlands

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Acknowledgements

Before you is the report 'The resilience of the farming system in Reusel regarding drought'. The study was conducted focusing on the farming system in Reusel. The report describes the current resilience of the farming system. Furthermore, the farming system of Reusel is defined, and an inventory of the prospects of drought in the area was made. The aim is to analyse the current resilience of the farming system in Reusel. The final result was created with the help of my supervisor from Wageningen University, and the farmers.

Firstly, I want to thank my supervisor Bregje van der Bolt. The completion of my thesis is due to her feedback and support. Hereby I would like to thank her for the effort during our discussions and meetings that helped me reflect better on myself and the report. I also want to thank Bregje van der Bolt and Wout Sommerauer for their aid to formulate the thesis topic.

Secondly, I would also like to thank the farmers for their time and effort in conducting the interviews. During the interviews, I learned more about the area and practices of the farming system. The results were not constructed without their help.

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Summary

Climate change is seen as an unavoidable environmental problem of the current century, and has a major impact on several climate aspects, such as drought. Drought sensitivity occurs due to precipitation deficit and the increase in evaporation. According to the KNMI (Royal Netherlands Meteorological Institute), the evaporation rate and the precipitation deficit will increase in the coming years. These processes have both a negative and a positive impact on Dutch agriculture, especially on the physical and fiscal impact of the farmer. Drought leads to increased vulnerabilities in agriculture, which can lead to concerns about the resilience of agricultural systems. The resilience per farming system varies due to the diversity of agriculture, farmers, and geographical differences. The focus is in Reusel with the main question: "What is the resilience of the farming system in Reusel by looking at the ecological drought challenge?"

The resilience of the farming system in Reusel was assessed by examining three capacities: robustness, adaptability, and transformability. This was done through literature review and qualitative data in the form of semi-structured interviews with farmers. A literature search has been conducted to get an overview of the general knowledge about drought and the environment of Reusel. Semi-structured interviews were held to look at the perspective of the farmers. The interviewed farmers were limited by the size of the farms. All five farmers owned more hectares of land than the average farmer in the Netherlands, by 59 ha for arable farmers and 55 ha for dairy farmers.

The agricultural system consists of arable farmers who produce potatoes, onions, maize, and sugar beets on sandy soils with a strong connection to livestock farming. Sandy soils are permeable to water, which results in a sensitivity to drought. Future scenarios of the climate show that the precipitation deficit increases during the growing seasons, as does evaporation. Due to the increase in precipitation deficit and evaporation, drought will occur more frequently over time. Drought affects both profitability and the quality of soil and water. Soil- and water quality is deteriorating due to a nutrient deficiency, which means limited quantitative and qualitative products. This reduces yield of farmers. However, the free market affects the sale of the products. This can ensure that yield does not decrease but increase. This difference depends on the diversity of farmers. The farmers that increased their income used measurements, such as irrigation, (controlled) drainage, drip system, holding water in weirs with iron plates, and compost.

This can ensure that farmers recover after a period of drought, looking at the current situation. This is not the case for profitability. Forty per cent describe they receive less income due to an increase in irrigation costs and the decrease in the quality of the produced products. Nevertheless, sixty per cent stated that they gain more yield, or it stays the same. The robustness in Reusel is moderate. The measures are linked to the adaptability of farmers. According to the interviews, farmers apply many measures against the drought. Hence, the adaptability of farmers is high. However, hardly any drastic changes have been implemented in the agricultural system. As a result, the transformability of the agricultural system is low. In general, the resilience of the agricultural system in Reusel is moderate.

Follow-up research could focus on the influence of the government on the farming system. Policies that involve farmers in decision-making processes can add valuable insights and tactics for addressing drought. Unique policy features can ensure that the resilience per farming system can increase by addressing the specific problems in that area.

Samenvatting

Klimaatverandering wordt gezien als een onvermijdelijk milieuprobleem van de huidige eeuw, en heeft een grote impact op verscheidene klimaataspecten zoals droogte. Droogtegevoeligheid treedt op door een neerslag tekort en de toename van verdamping. Volgens het KNMI (Koninklijk Nederlands Meteorologisch Instituut) zullen de hogere verdampingssnelheden en het neerslagtekort de komende jaren toenemen. Deze processen hebben zowel een negatieve als positieve invloed op de Nederlandse landbouw, vooral op de fysieke en financiële impact van het landbouwsysteem. Droogte leidt tot grotere kwetsbaarheden in de landbouw, wat kan leiden tot zorgen over de veerkracht van de landbouwsystemen. De veerkracht per landbouwsysteem varieert door de diversiteit aan landbouw, agrariërs en geografische verschillen. De focus is het gebied rond Reusel, met als hoofdvraag: *"Wat is de veerkracht van het landbouwsysteem in Reusel door te kijken naar de ecologische droogte uitdaging?"*

Met behulp van drie capaciteiten: robuustheid, aanpassingsvermogen en transformeerbaarheid, is de veerkracht van het landbouwsysteem in Reusel onderzocht. Dit is gedaan door middel van een literatuuronderzoek en kwalitatieve data in de vorm van semigestructureerde interviews met agrariërs. Een literatuuronderzoek is uitgevoerd om een overzicht te krijgen van de kennis van droogte en de omgeving van Reusel. Na het literatuuronderzoek zijn semigestructureerde interviews gehouden om te kijken naar het perspectief van de agrariërs. De geïnterviewde agrariërs zijn beperkt gebleven door de omvang van de bedrijven. Alle vijf agrariërs hadden een aanzienlijk percentage aan hectare grond dan een gemiddelde agrariër in Nederland.

Volgens agrariërs en literatuuronderzoek bestaat het landbouwsysteem voornamelijk uit akkerbouwers die aardappelen, uien, mais en suikerbieten produceren op zandigere gronden met een sterke samenhang met veehouderijen. De zand gronden van het landbouwsysteem zijn waterdoorlatend, wat zorgt voor een sterker effect van droogte. Droogte is door de KNMI in kaart gebracht met vier scenario's. In alle scenario's komt naar voren dat het neerslagtekort tijdens de groeiseizoenen toe neemt, evenals de verdamping. Door de toegenomen verdamping en neerslagtekorten zal droogte vaker optreden in de loop van de tijd. Droogte heeft zowel invloed op financiële aspecten als de kwaliteit van bodem en water. De bodem- en waterkwaliteit gaan achteruit door een nutriëntentekort, wat voor beperkte kwantitatieve en kwalitatieve producten zorgt. Hierdoor dalen de opbrengsten van de agrariërs. Echter heeft de vrije markt invloed op de verkoop van producten. Dit kan ervoor zorgen dat de opbrengsten niet dalen, maar stijgen. Dit verschil hangt af van de diversiteit aan agrariërs en de toegepaste maatregelen. Agrariërs met een verhoogd inkomen, gebruikten maatregelen zoals irrigatie, (gecontroleerde) drainage, druppelsysteem, water vasthouden in stuwen met ijzeren platen en compost. Desalniettemin gebruikten andere boeren exact dezelfde maatregelen tegen droogte, maar toch kregen de boeren minder opbrengst. De melkveehouder gebruikte metingen voor irrigatie, het vasthouden van water en het verhogen van de organische stof in de bodem. De melkveehouder gebruikte geen andere maten voor zijn land.

Dit kan ervoor zorgen dat de agrariërs zich kunnen herstellen na een periode van droogte, kijkend naar de huidige situatie. Integendeel is dit met de winstgevendheid. Hierdoor hebben de agrariërs een gematigde robuustheid. De maatregelen zijn gelinkt aan het aanpassingsvermogen van de agrariërs. Volgens de interviews passen agrariërs veel maatregelen toe tegen de droogte, en hebben de agrariërs een hoger aanpassingsvermogen. Echter zijn nauwelijks drastische veranderingen geïmplementeerd in het landbouwsysteem. Hierdoor is de transformeerbaarheid van het landbouwsysteem laag. In het algemeen is de veerkracht van het landbouwsysteem in Reusel gematigd.

Eventueel vervolgonderzoek zou zich kunnen richten op de invloed van de overheid op het landbouwsysteem. Hierbij kan gekeken worden naar de meningsverschillen van agrariërs en de wisselende resultaten van het literatuuronderzoek op de opbrengsten. Dit kan van grote invloed zijn op de toekomstige visie van veerkracht in Reusel. [1]

[1] The research took place in Reusel, the Netherlands, and the interviews were held in Dutch, it was decided to add a Dutch summary to the report.

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1. Introduction

Climate change is seen as an inevitable environmental problem of the current century (Yousefpour et al., 2015). Climate change has an impact on drought sensitivity through precipitation, temperature, potential evapotranspiration, and soil moisture (Philip et al., 2020). Due to an increase in evaporation by higher solar radiation and precipitation deficit, drought will occur more frequently (Kennisportaal klimaatadaptatie, n.d.). This is also seen in the summer and spring in the Netherlands of 2022. According to the Royal Meteorological Institute of the Netherlands, the higher evaporation rate, and the precipitation deficit will increase in upcoming years (KNMI, 2022).

Responding to changing weather conditions is essential for different sectors, especially agriculture. The Dutch ground is divided into almost 50% agriculture (Centraal Bureau voor de Statistiek, 2022). Agriculture is an important pillar of the Dutch economy through the production of food and the export of agricultural products, which will decrease if agriculture does not adapt (STOWA, 2021). Drought has an impact on agriculture in many ways, both economically, and physically. Positive and negative changes occur; some changes have direct consequences, and others have indirect consequences. The direct consequences are the changing crop production and crop yield decrease. Indirect consequences are the new diseases and pests, which have a physical- and fiscal impact on the farmer's plots. On the other hand, higher temperatures will improve crop production, but without excess (STOWA, 2021).

The impact of the drought will lead to a higher vulnerability in agriculture, which could lead to concerns about the resilience of the farming systems (Meuwissen et al., 2019). To determine the resilience of the farming system, three capacities must be considered: robustness, adaptability, and transformability. First, robustness is the ability that looks at if the farming system can withstand the impact of drought, and it will recover quickly (Meuwissen et al., 2019). Next, adaptability looks at if the farming system can adapt to the consequences of drought (Meuwissen et al., 2019). Lastly, transformability analyses how easily and how willing the farming system can change or reorganize with the challenge of drought. These three capacities estimate the resilience of the farming system (Meuwissen et al., 2019).

The resilience of the farming systems needs to be investigated in a regional context due to the diversity of farms, farmers, and local environments (Meuwissen et al., 2019). Farms consist of arable farming, horticulture, grazing livestock farms, pen farms, and crop- and livestock combinations. Drought can impact the activities of each type of farming practice differently. For example, livestock farming will feel the impact of heat stress more compared to arable farming, which is impacted by decreased crop growth (Centraal Bureau voor de Statistiek, 2022). The difference between farms is also influenced by the local environments. Drought indicators, such as precipitation, temperature, ground- and reservoir water levels, soil moisture, and streamflow differ from place to place. The soil moisture depends on the soil type. Sandy soils are permeable to water and the lack of water retention may lead to drought (Remmelink et al, 2018). Due to the diversity of farms, farmers, and local environments, the resilience will differ in a regional context. By concentrating on the area around Reusel, the indication of resilience will be more accurate. Reusel is a village in the municipality of Reusel-De Mierden in the province of North-Brabant.

This project aims project to assess the resilience of the farming system in Reusel. Knowledge of the current resilience of the agricultural system in Reusel can lead to improvements that will enable better responses against exceptional drought in the future (KNMI, n.d-a.). Therefore, the main- and sub-questions are:

"What is the resilience of the farming system in Reusel by looking at the environmental drought challenge?"

a. What is the definition of the farming system in Reusel?
b. What is the current situation regarding drought, and how will drought develop over time?
c. What is the influence of drought on the produced goods of the farming system?
d. How robust, adaptable, and transformable is the farming system of Reusel?

This report is structured in the following way. In the next section, a brief description of the theoretical framework is given. Section three explains the methodology, section four describes the results of the literature review and interviews, section five discusses the results, and at last section six gives the conclusion.

2. Theoretical framework

To assess the resilience of the farming system in Reusel, a resilience framework by Meuwissen et al. (2019) is used. The framework is used to research system properties, challenges, main functions of the farming system, and resilience capacities. The capacities refer to the adaptive cycle and the processes, such as risk management, governance, farm demographics and agricultural practices. The adaptive cycle is a model that responds to changing environments and internal dynamics. The cycle derives from ecological system thinking, through which the system changes into various stages, such as growth, conservation, collapse, and reorganization, see

Figure 1. Farming systems are different from ecological systems in their aim of production as well as their purposeful endeavours to control their surroundings and avoid environmental damage (Walker et al., 2004). Applying the concept of the adaptive cycle to a farming system acts as a heuristic that directs attention to system change (Walker et al., 2004). For example, if the farming system copes with potential challenges, risk management may be used to ensure that the systems maintain or quickly return to their previous state (i.e., conservation). The challenges can also result in the degradation of the agricultural system (i.e., collapse). These challenges may affect an entire area or field plots. A farming system may not go through all stages of the adaptive cycle. In practice, the challenges are less static than in the theoretical description (Meuwissen et al., 2019).

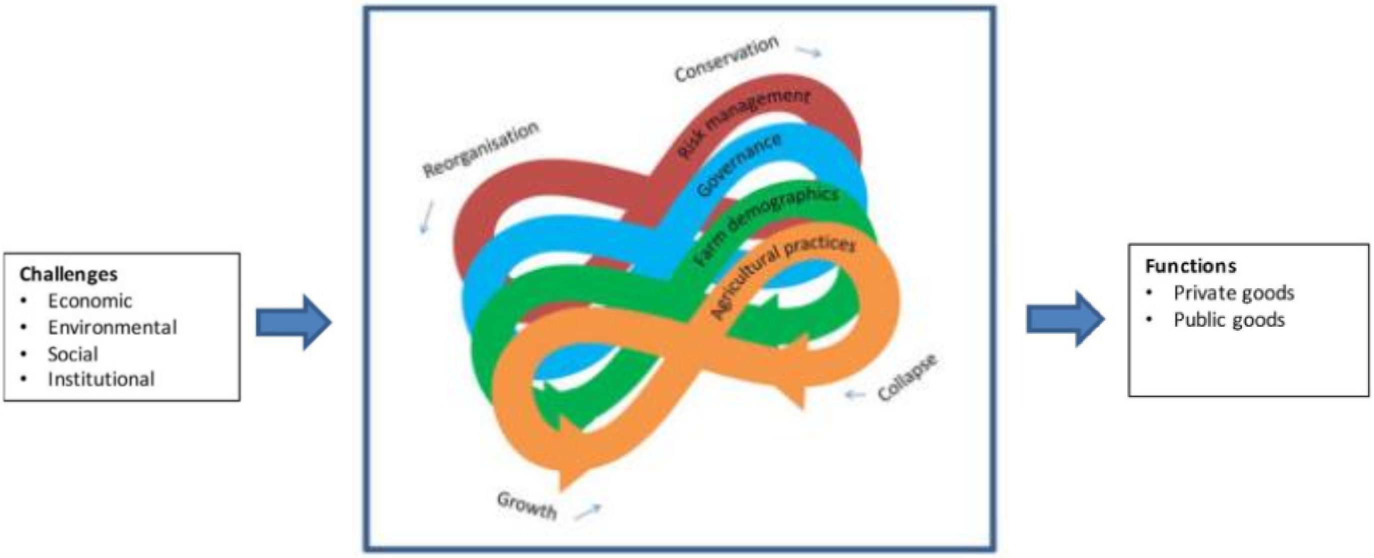

Figure 1: Adaptive cycle in agriculture (Meuwissen et al., 2019).

The resilience framework focuses on the ability or capacity to foresee and manage challenges and to recover from their effects quickly and effectively. Resilience is a broad concept with different meanings. During this research, socio-ecological resilience is used. The definition of socio-ecological resilience is: "its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability, and transformability" (Meuwissen et al., 2019). The three capacities are selected from a social-ecological perspective. Moreover, there is a connection between the ecology of a system and farmers because farmers (un)consciously exert influence on the system. Furthermore, farmers are dependent on ecosystem services, such as the production of food and regulating the nutrients in the soil (Bennett et al., 2009). It is determined to focus on socio-ecological resilience in this thesis due to the interaction between farmers and agriculture.

The three capacities are important to understand the resilience of the farming system. They explain the description of socio-ecological resilience. Robustness is also defined as persistence. It is the capacity that a system can absorb and remain in the system state for a short duration. Adaptability capacity is the adjustment of a system that reacts to evolving external factors and internal processes, which enables evolution within the existing system state for a moderate time period. Transformability is the capacity whereby the system transforms into a new system state for development in the long term (Folke et al., 2010).

The resilience framework by Meuwissen et al. (2019), considers the level of the farming system, the build-up of challenges, and agricultural processes as the primary scale. It also focuses on the fact that farming systems serve a variety of purposes that can vary over time. The resilience framework by Meuwissen et al. (2019) is formed for specific resilience as well as general resilience. In this thesis, the focus is on specific resilience to drought. The resilience consists of five steps, see Figure 2. Step five addresses general resilience and will not be addressed in this thesis.

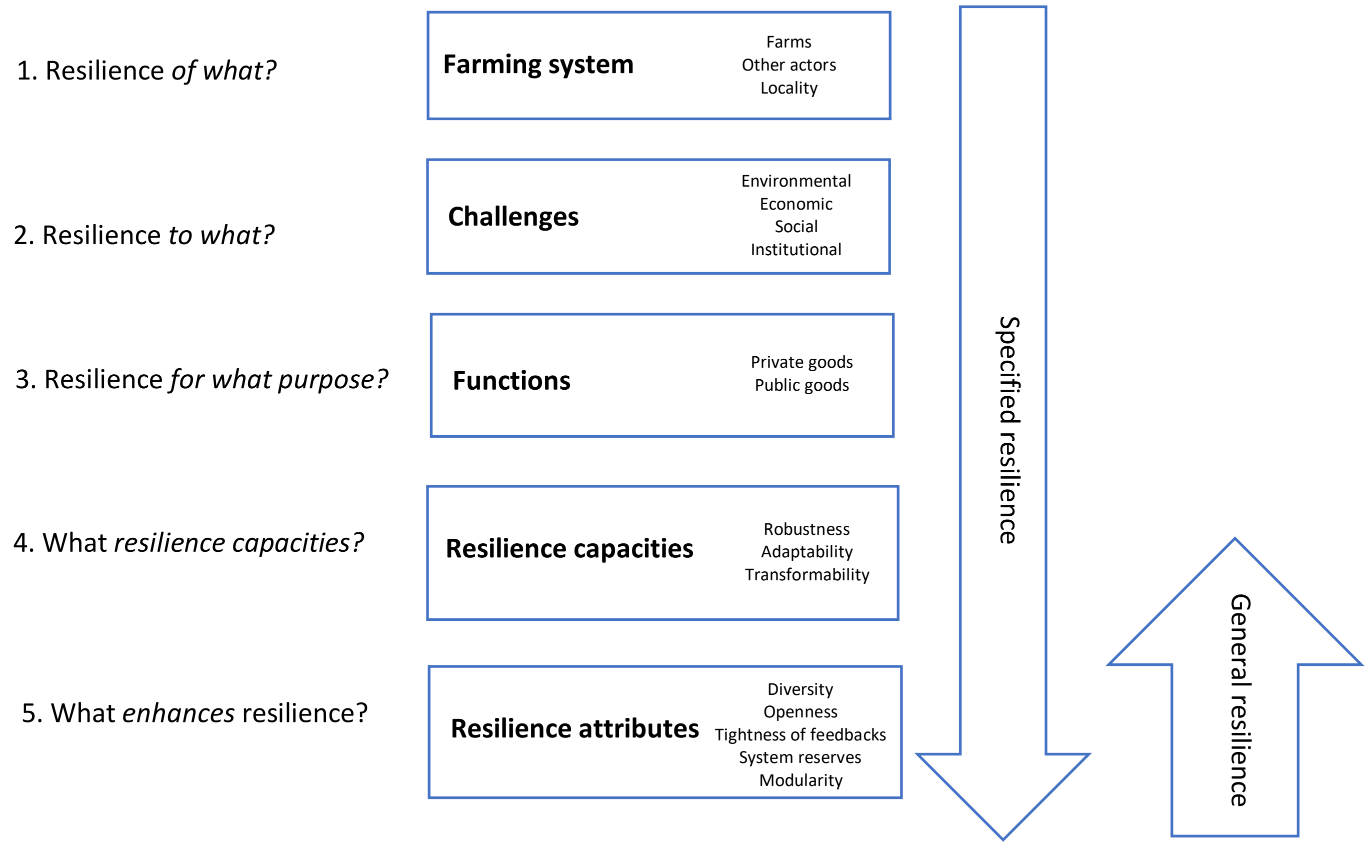

Figure 2: The methodology of the resilience framework of a farming system adjusted from Meuwissen et al., 2019.

2.1 Resilience of what?

The first step is characterizing the farming system. By definition, a farming system is a structure in which the core consists of farmers that produce the main products in the region (Meuwissen et al.,2019). This also includes other actors that mutually influence each other. Actors that only influence or are influenced by the farming system are not part of the system, such as the media, consumers, and policymakers. However, these other actors should be considered due to the influence that they have on the farming system. Figure 3 shows the farming system and the other actors that should be considered in characterizing the farming system (Meuwissen et al., 2019).

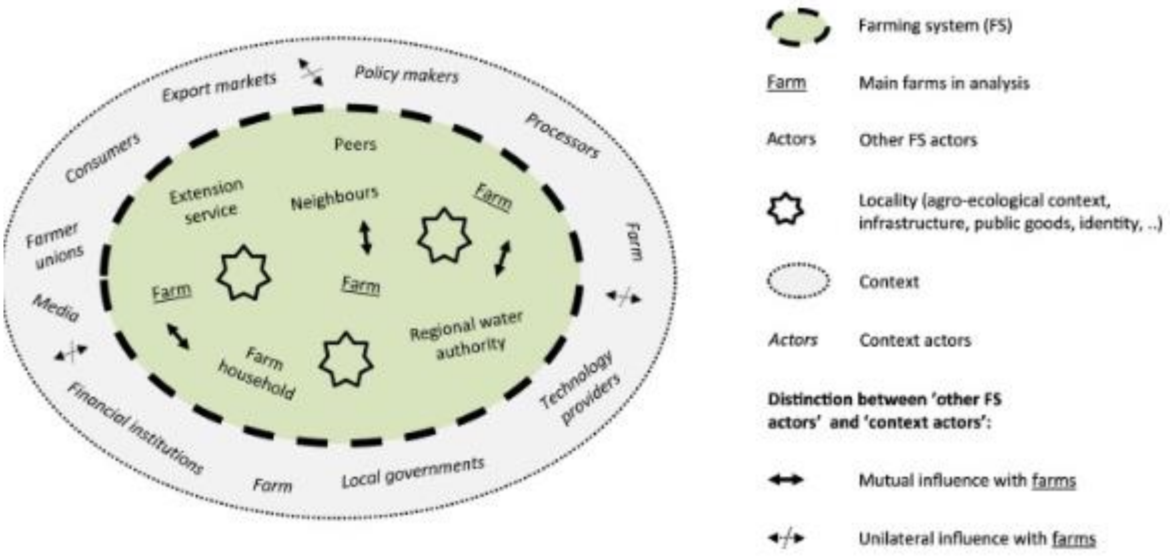

Figure 3: A farming system and other actors that should be considered in characterizing a farming system (Meuwissen et al., 2019).

There are several types of farming systems. To include all these farming systems, the comparison between different sets will be done by looking at five aspects:

1. Challenges, such as environmental or economic challenges for drought. An environmental challenge can be the deterioration of soil and water. An economic challenge is the increase in irrigation costs.
2. Agroecological zoning. To estimate the potential of agricultural production systems, agroecological zoning entails the inventory, characterization, and classification of the physical environmental resources. The components, of climate, soil, and landform, which are essential for the availability of water, energy and other resources are among these physical resources (Oldeman & van Velthuyzen, 1991). The focus of agro-ecologicial zoning lies on the impact of drought on the soil- and water system. Type of farming, thus sector, intensity, size, and organizational form.
3. Production capacity, focusing on the quality of the product. The main products of the farming system will be described.
4. Public good's effect on landscape, biodiversity, or water quality. The impact of the main products on the environmental aspect of drought will be researched.

These aspects are different per farming system. In this thesis, the type of farming and production are considered in the research questions.

2.2 Resilience to what?

This step identifies the key challenges of the farming system. The challenges are divided into economic, environmental, social, and institutional challenges. These challenges can hinder the optimal public and private goods that the farming system produces. There are two types of challenges: shocks and long-term stresses (Meuwissen et al., 2019). Shocks consist of permanent or temporary impacts on the farming system. This depends on the resilience of the system. Step-by-step changes, such as the ageing of farmers or transition in the food behaviour of consumers, which builds up in the farming system are called long-term stresses. An increase in shocks and long-term stresses will potentially lead to a higher vulnerability of the farming system, which could in turn lead to the crossing of critical thresholds, such as soil degradation (Meuwissen et al., 2019).

2.3 Resilience for what purpose?

Step three identifies the produced private and public goods of the farming system. Private goods contain the production of healthy and affordable food sources and other bio-based resources. Private goods ensure that people working in agriculture have a decent standard of living and enhance the standard of living in rural communities by creating jobs and offering fair working conditions. Public goods include the preservation of natural resources, the well-being of biodiversity and the attractiveness of rural areas as places to live and visit. The impact that the farmers face is divided into economic, agriculture and nature (Meuwissen et al., 2019). The economic impact of drought focuses on profit, income from agricultural activities, land prices and crop yield. Crop yield indicates the impact of climate on agriculture by viewing the potential and the actual income (STOWA, n.d.). Agricultural impact consists of crop production, soil- and water quality. The impact of drought on nature looks at biodiversity, and damage to nature in general. The assessment is done through indicators, such as food production, economic viability, and natural resources. The indicators are divided into sub-indicators (Meuwissen et al. 2019).

1. Food production
    a. Starch potato production (t/ha)
    b. Sugar beet production (t/ha)
2. Economic viability
    a. Profit (Euro/ha)
    b. Income from agricultural activities (%)
3. Natural resources
    a. Responsible use of nutrients
    b. Soil quality

If the system is unsustainable, then the balanced provision of public and private goods cannot be sustained. Reform may be necessary (Meuwissen et al., 2019).

2.4 What resilience capacities?

This step is assessing the resilience capacities: robustness, adaptability, and transformability (Meuwissen et al., 2019). Robustness describes how much the farm can bear the shocks, and if the farm can recover from that. Adaptability shows if the farm can adapt or change against shocks or long-term stresses without transforming the system's structural elements. Transformability states if the farmer is willing to radically change or reorganise the farm to deal with the shocks or long-term stresses. The results describe the resilience of the farming system (Meuwissen et al, 2019).

3. Methodology

Answering the research (sub-)question(s) consisted of using the resilience framework. In addition, the research focuses on the perspective of the farmers and the challenge of drought. The following questions were:

"What is the resilience of the farming system in Reusel by looking at the environmental drought challenge?"

a. What is the definition of the farming system in Reusel?
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d. How robust, adaptable, and transformable is the farming system of Reusel?

Within these steps, primary and secondary data collection was used. The collection consists of a literature review and qualitative data in the form of in-depth interviews. The elaboration of the literature review and semi-structured interviews is explained in detail below. The project focuses only on the perspective of the farmer and drought.

3.1 Primary- and secondary data collection

The primary- and secondary data collection consists of a literature review and qualitative data in the form of in-depth interviews with farmers. The literature review was done to create an overview of the knowledge on drought and the area of Reusel. After the literature review, in-depth interviews were held to look at the perspective of the farmers.

Literature review

In collecting information for this literature review, multiple databases were used. Google Scholar was used to gathering a preliminary sample of types of articles that target drought in the Netherlands or on sandy soils. The library of Wageningen was used for its diverse collection of databases, such as ScienceDirect, and Groen Kennisnet. There were diverse types of search terms used for every sub-question. The search terms for sub-question A were produced goods, water management, Reusel, livestock- and arable farming, and sand soil. Sub-question B consisted of the search terms evaporation, precipitation, and future drought. At last, the search terms drought fiscal impact, and soil- and water quality by drought were used for sub-question C. In addition to database searching, the snowball method was used to locate several articles. The appropriateness and relevance of each search phrase were considered concerning the goal of this literature review.

Scientific articles in refereed publications or professional organizational sites were researched by the same search terms, such as Climate atlas. At last, grey literature was used, such as the KNMI, Province of North-Brabant, Wageningen UR, Union of Waterboards and PDOK with geo-information from Kadaster. The articles that were used focused on drought portal, drought on sandy soils in the North Brabant, and the economic effect of drought in agriculture in the Netherlands. From PDOK the databases Agricultural Area of the Netherlands (AAN) and Basic Registration Crop Fields (BRP) were used to identify the crop in the area.

Semi-structured interviews

The collection of information from the farmers was done in the form of semi-structured interviews. A semi-structured interview consists of open questions, whereby the answers given during the interviews can be discussed in more detail (Bickman & Rog, 2009). This specific research method was chosen because of these motives and the same working method as the SURE-Farm project. The interviews were held in Dutch, since this was the native language of the farmers. In-depth interviews focused on seeing from different sides, such as a farmers' vision in practice. The in-depth interview was based on themes: introduction, farming system, current challenges, the impact of drought, resilience, and closure. Based on the farm survey from Spiegel et al., (2019), the interview-question in were chosen, see Appendix I. The questions were adjusted to open questions instead of closed questions. The respondents were chosen based on the snowball method. The participant information sheet with the survey questions was sent two days before the interview took place. All the respondents lived near Reusel or had their plots in Reusel. The respondents consist of eighty per cent arable farmers and twenty per cent livestock farmers. Due to different circumstances, the interviews were held online through MS Teams. During the interview, it was explicitly asked whether the conversation can be recorded.

The interviews were transcribed and coded. Non-verbatim transcription was used in this research. The whole conversation was registered, except hesitations, and stuttering. This was done through the audio recording on MS Teams. The full audio recording of the interviews was saved in MS Teams (Smits, 2021). The results of the interview were transcribed in Word. The second step was to encode the transcripts. The answers are processed with tables in the Excel program. After the answers were written in Excel, encoding started with open coding. The textual data was broken up into discrete parts and labelled with codes. After this, axial coding was performed. The connections between designated codes were made and compared with each other into categories. The last step was selective coding. The connected categories were associated with one core category.

3.2 The steps of the resilience framework

Step 1: Resilience of what? - What is the definition of the farming system in Reusel?

Identifying the farming system was done through primary– and secondary data collection. Firstly, a literature review was done to get an overview of the farming system using secondary literature. It was divided into the actors and locality. It refers to the farm type, the produced goods, and the quality of the regional area, such as soil and water. The area near Reusel was described, as well as the stakeholders that have mutual influence on each other. After the literature review, primary data collection was conducted by in-depth interviews. The purpose of the in-depth interviews was aimed at checking whether the farming system was correct from the farmers' perspective in comparison with the literature review.

Step 2: Resilience to what? – What is the current situation regarding drought, and how will drought develop over time?

The second step was fulfilled by secondary data collection. This consisted of a literature review by looking at the developments over time for drought. Drought was analysed through precipitation and evaporation. The database of KNMI (Royal Netherlands Meteorological Institute) was used for information about precipitation and evaporation. The farmer's perspective of drought on their farms was described with the aid of in-depth interviews. The questions were focused on the main challenges and strategies for their farm with regard to drought.

Step 3: Resilience for what purpose? – What is the influence of drought on the produced goods of the farming system?

Step three describes the impact of drought on agriculture. In-depth interviews were used to determine the influence of drought on the farming system. The impact of drought consisted of an economic and environmental factor. The economic factor contains the yield and loss of the produced goods. The environmental factor focuses more on the quality of the soil and water of the plots.

Step 4: How robust, adaptable, and transformable is the farming system of Reusel?

Step four illustrates what the resilience is of the farming system by looking at robustness, adaptability, and transformability. To answer the sub-question, in-depth interviews were used. Robustness focuses on the rebounding from the current situation and profitability of the farm after a period of drought.

Adaptability looked at the implementation of technologies that were used to decrease the impact of drought, and the time management of the farmer to realise those technologies. At last, transformability consisted of the decisions that made a resulted change on their farm by looking at the problems and easy changes that the farmers encountered.

4. Results

In this chapter, the results of the qualitative research are described. The results consist of the description of the farming system, the developments of drought over time, the impact of drought on the farming system and the three resilience aspects in relation to the farming system.

4.1 Farming system

The farming system in Reusel consists of knowledge about the quality of the area, the farm type, and the produced goods.

The majority of the agriculture farms are used for intensive livestock- and arable farming. The primary crop is potatoes. This corresponds with eighty per cent of the respondents. They stated that potatoes are the most important produced goods. Although sugar beets, corn and other crops are grown there as well (Esri Nederland, 2021).

In the area of Reusel, horticultural farms and nursery businesses are extremely rare. Cattle and intensive grazing of animals dominate agriculture in the green main structure. The dominant livestock type is dairy cattle and meat pigs, based on the number of stables in Reusel (Provincie Noord-Brabant, 2022). Sixty per cent of the respondents explained the importance of the cohesion between arable and livestock farming. With the aid of cohesion, animal manure is an excellent product to make sandy soils more water retentive. Both businesses typically operate from a single farm. Land-based agricultural areas with hard structures are found close to Reusel (Provincie Noord-Brabant, 2006).

This can be due to the water quality and quantity in Reusel. Irrigation water comes from the catchment of the Dommel and precipitation (Provincie Noord-Brabant, 2006). The physical and chemical water quality is poor due to all kinds of discharges (Coördinatiecommissie Integraal Waterbeleid, n.d.).
The primary sources of discharges are agricultural land and wastewater from treatment facilities. The majority of still waters have water quality that follows the established goals, with nutrient richness ranging from extremely deficient to abundant. Local groundwater is influenced by the fertilization of agricultural land, which causes an abundance of nutrients. Areas of stream valleys typically flood for a considerable amount of time during wet months, particularly in the winter and spring (Provincie Noord-Brabant, 2006).

This may be due to the sandy soil in Reusel. They are distinguished by their dryness, lack of nutrients and low calcium content (Provincie Noord-Brabant, 2006). Sandy soils were fertilized to produce humus podzol soils. Sandy soils are characterized by their dryness (Provincie Noord-Brabant, 2006). This is due to the lutum- and loam content. Lutum percentage can differ from 0 to 8%. A higher lutum percentage indicates a higher adsorption capacity, which forms an increase in moisture-binding capacity. However, sandy soils have a lower percentage of lutum. As a result, sand has no adsorption capacity and has a low moisture-binding capacity. This makes sand permeable to water. The soil particles have no binding to water (Remmelink et al., 2018). Cracks will arise in the sandy soils, and nutrients will leach out (Groffen et al., 2017). According to Dolit et al. (2022), organic matter can increase water retention capacity. The organic matter in the sand is between 0 to 15%. A higher percentage of organic matter results in improved water-absorbable soil. In addition, organic matter actives soil life, which ensures a balance between air and moisture in the soil. It increases the soil's resistance to diseases and pests. Sandy soils are sensitive to drought due to their low lutum and organic matter content (Remmelink et al., 2018).

4.2 Drought

The resilience of the farming system in Reusel depends on the current drought. Therefore, the years of 2022 and 2023 have been included in the study. The development of drought in the future was also examined. From the result, it can be concluded whether the current resilience is sufficient for future drought.

Drought is caused by a lack of precipitation and/ or an increase in evaporation. The SGI (Standardized groundwater index) takes into account variations in groundwater levels and precipitation time series (Bloomfield, 2013). The SGI scores can be seen in Figure 4.

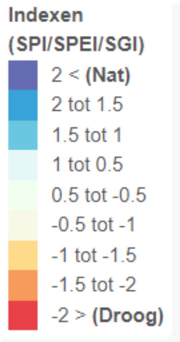

Figure 4: The indices color explanation for wet or dry areas (Unie van Waterschappen & Interprovinciaal Overleg, n.d.)

The number index per point difference over time. Figure 5 illustrates how dry the area is with the black line in the year 2022. The red line is the reference line for 2018. The year 2018 is chosen because of the exceptional drought in that year. There were a lot of harmful consequences, such as damage to crops, plants and animals. It also led to the understanding that the current freshwater system was too fallen short. The drought affected the soil, ground- and surface water (van den Eertwegh et al., 2021).

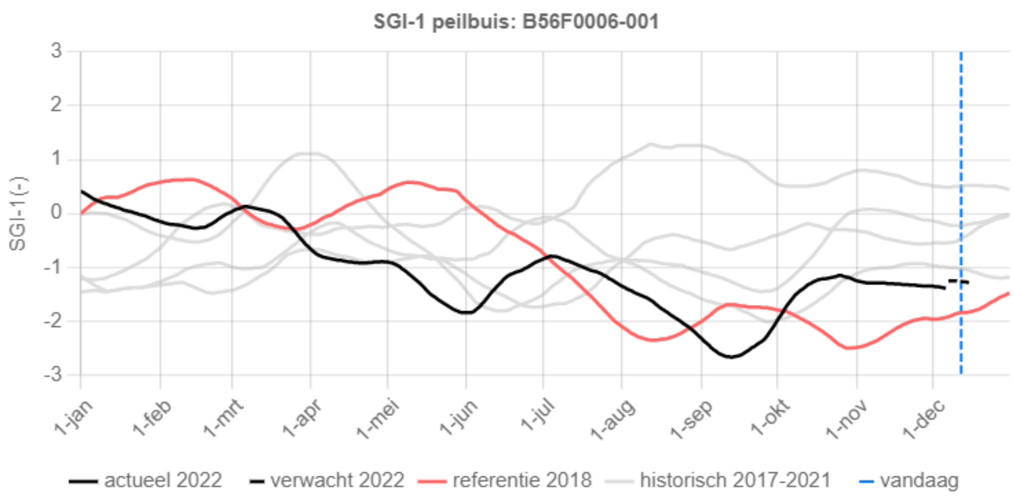

Figure 5: The index of SGI of the area in point one illustrates of the year 2022 with the reference of 2018 (Unie van Waterschappen & Interprovinciaal Overleg, n.d.).

The black line is decreasing over time. This can be explained by high evaporation due to the summer. The black line forms the descending line with the red line. From the months of April to July, the black line is even below the red line. The SGI-index was -2>, which means a dry environment. The groundwater level was in the summer around 27.5 m +NAP (Normal Amsterdam Level), whereby the ground level is 30.5 m +NAP. In the Netherlands, the groundwater level is expressed in relation to the Normal Amsterdam Level. Normally, the groundwater level in the Netherlands is less than two meters below ground level (Lindy, 2017). In the year 2022, the groundwater level in Reusel is more than two meters below ground level (Uni van Waterschappen& Interprovinciaal Overleg, n.d.).

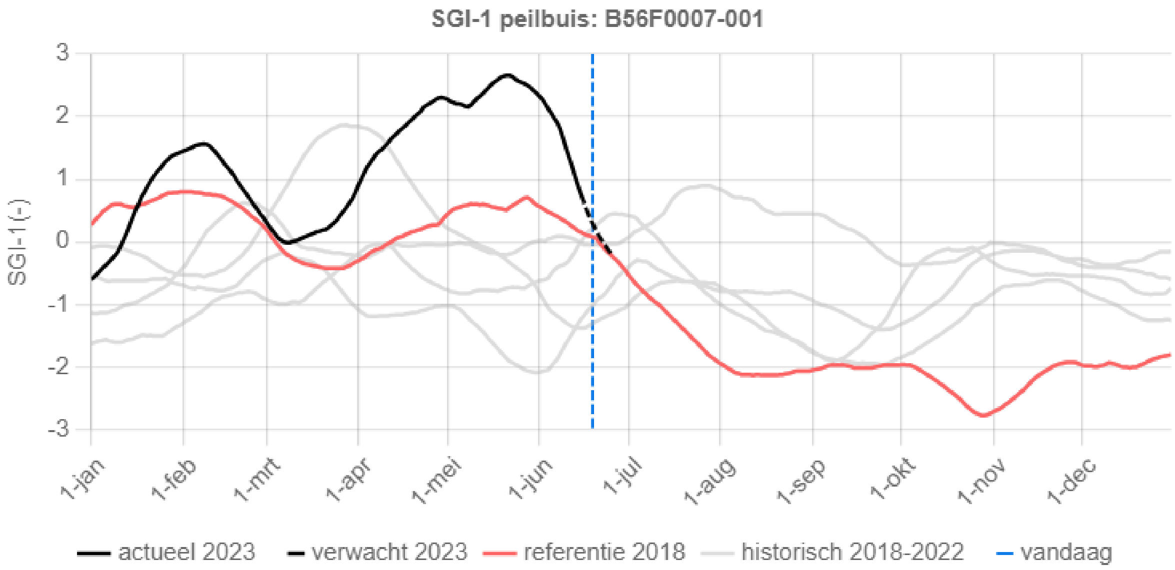

Figure 6: The index of SGI of the area in point one illustrates of the year 2023 with the reference of 2018 (Unie van Waterschappen & Interprovinciaal Overleg, n.d.).

Figure 6 shows the current situation with drought. The SGI between April and June scored higher than two, which indicates wet conditions. In May, significantly more precipitation occurs than average in Reusel. The official dry season's first months were wet. The groundwater reserves have increased in volume. For the time of year, the groundwater levels are higher than in previous years (Van Zijl, 2023). At the moment, the SGI scores between 1 and 0, which indicates a little bit wet to neutral. The dashed line shows the expectation for the previous weeks and predicts a drier area.

The agriculture sector suffers from drought. It is challenging to predict drought in the future, especially for evaporation. However, KNMI developed climate scenarios using model simulations for the Netherlands in 2014 (KNMI, 2018). The scenarios are used to implement adaptation strategies, and show four potential future perspectives, see Figure 7. The scenarios are based on the differences in increase of temperature, moderate and warm, and changes in airflow patterns, low pressure, and high pressure.

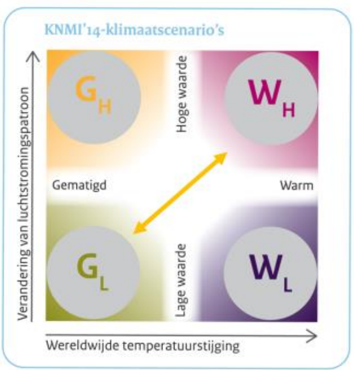

Figure 7: KNMI'14 Climate Scenarios (KNMI, 2018).

The climate scenarios'14 sketch higher temperatures, rising sea levels, wetted winters, heavier precipitation, and drier summers. Table 1: Key figures KNMI'14 climate scenarios round 2050 (KNMI, n.d.-b). shows the differences of precipitation, evaporation, and drought in the four scenarios. The percentage is based on the reference period of the KNMI'14 climate scenarios from 1981 to 2010 (KNMI, n.d.-b).

Table 1: Key figures KNMI'14 climate scenarios round 2050 (KNMI, n.d.-b).

Variable	Indicator	Climate 1981-2010	G_L	G_H	W_L	W_H
Precipitation	Number of wetter days	43 days	+0.5%	-5.5%	+0.7%	-10%
Evaporation	Potential evaporation	559 mm	+3%	+5%	+4%	+7%
Drought	Average highest precipitation deficit during the growing season	144 mm	+4.5%	+20%	+0.7%	+30%
	Highest rainfall deficit exceeded once every ten years	230 mm	+5%	+17%	+4.5%	+25%

Table 1, present a decrease in the number of days with wetter conditions in high-pressure zones, but there is a slight increase of 0.7% in wetter days with low-pressure zones. The evaporation and drought increase in all four scenarios. The annual reference evaporation is around 610 – 630 millimetres. This can be seen in Figure 8. Reusel is marked as the circle in Figure 8. The annual reference evaporation is based on the highest climate change scenario in 2050.

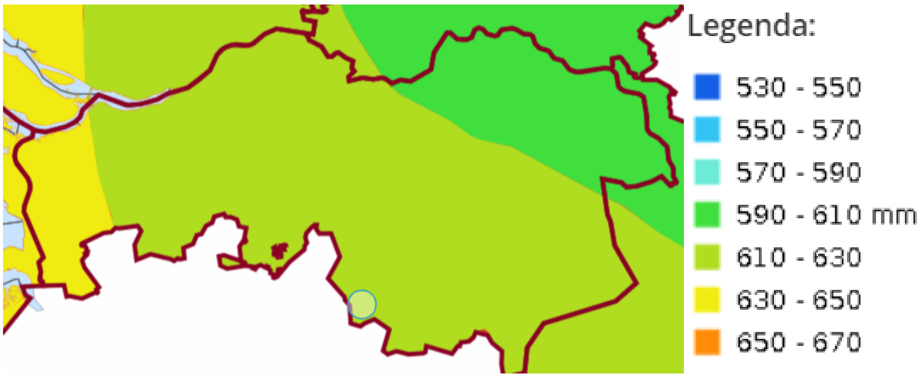

Figure 8: The annual reference evaporation of the province of North-Brabant and the legend (Klimaateffectatlas, n.d.).

The indicators of drought in the climate scenario also shows an increase with all the scenarios. Table 1, shows that the high-pressure zone presents a larger increase in precipitation deficit than the lower-pressure zone. The high-pressure zone is slightly larger for upcoming events, enhancing drought conditions. The springtime is drier, warmer, and sunnier. The precipitation deficit rises and does so in the future at a faster rate than nowadays (van der Wiel et al., 2021).

In Figure 9 can be seen the potential maximum precipitation deficit (once every 10 years). Reusel is marked as a circle. The results of the map layer are coming from the highest climate change scenario of 2050.

Figure 9: The potential maximum precipitation deficit in the Province of North-Brabant (once every 10 years) and the legend (Klimaateffectatlas, n.d.).

The potential maximum precipitation deficit in Reuse once every 10 years is around 300 – 330 millimetres. In dry months, the precipitation deficit is around 100-200 millimetres (Doggenaar, 2022). Compared this to Figure 9, the precipitation deficit in the future will increase to 300 – 330 millimetres once every 10 years.

Precipitation deficit and evaporation will increase over time, which results in frequent and longer drier periods. With the increase in drought, it is just as important to be resilient now as it will be in the future. Drought has an impact on the farming system, and thus the quality of the area and produced goods.

4.3 Influence of drought

The impact of drought depends on the amount of rainfall in a period, geographical locations, and the crop's growing season. The farmer cannot control these factors. A geographical aspect is the soil- and water quality. It has certain properties depending on the structure. Sandy soils near Reusel are high dry and low wet soils due to the subsurface groundwater flow caused by the stream in the valley. The stream collects the groundwater and disposes of it in the winter and summer. However, in the summer the amount of water is less available than in the winter due to evaporation. Evaporation takes place from the stream through the soil via agricultural crops (Van Den Eertwegh et al., 2021).

Evaporation causes a lack of soil moisture. The extraction of groundwater and/ or surface water in sandy areas will strengthen this process (Van Den Eertwegh et al., 2021). Farmers irrigate their crops using water from nearby streams or groundwater. As water in the streams dries out, farmers are increasingly using groundwater as a course for irrigation. The implementation of restrictions on the extraction of surface water increases the usage of groundwater. However, using groundwater for irrigation during a drought only makes the situation worse. Agriculture enhances the groundwater and run-off drought. Therefore, using groundwater for irrigation has a detrimental effect on the water system. On a broad scale, they cause a further decline in groundwater levels as well as a further reduction in stream flows and seepage (Van Den Eertwegh et al., 2021). By forty per cent of the respondents, occurs a limitation of water. The interviewed farmers irrigate more or less on certain parts of their land due to the differences in sandy soils. Heavy sandy soils suffer less from drought and need to be irrigated twice per week. The opposite is with light sandy soils. Farmers need to irrigate six times for the same quality of products on light sandy soils according to the farmers. An arable farmer stated that the soil texture becomes harder, but there is no decrease in soil quality. In the winter, the soil texture must recover the moisture-retention capacity. Irrigation only causes moister in the top layer of the soil. Irrigation is therefore not always an option when growing crops with a large water requirement on soils with a suspended water profile.

Evaporation will continue even if it is not raining, because of water near the roots. The groundwater levels and soil moisture drop due to dry conditions and the fact that precipitation decrease. The flow of groundwater decreases because gradients in the groundwater become smaller. If this process continues, the water flow to the stream will decrease and eventually dry out (Van Den Eertwegh et al, 2021). Nutrient leaching from the soil is reduced with drier soils. Nutrients ensure healthy soil life and the growth of crops. Forty per cent of the respondents experience a decrease in soil quality due to the limitation of nutrients. The slower rate of crop growth results in less nutrient uptake. As a result, both the levels of nutrients that are accessible to plants and the stock of nutrients in the soil rise (Eurofins Agro, 2020a). Precipitation ensures that the nutrients will wash out in a dry period. Plant growth cannot be optimized, and crop yield can decrease (Eurofins Agro, 2020b).

Crop yields are typically used to describe how climate has an impact on agriculture. Here, the terms “potential yield,” and “actual yield” are distinguished. Potential yield is the amount of yield that could be produced given environmental factors, such as water, temperature, and CO_2- concentration. Actual yield is the income of the market product. The actual output is lower because nutrients and water are never optimally available and/or there is damage from contaminants. Diseases and pests can also restrict growth. By enhancing varieties and altering sowing dates, one might boost potential yield. By implementing fertilizers, pesticides, irrigation and other advancements in technology, the gap between potential and actual production can be narrowed (STOWA, 2021).

A step in determining economic impact is to identify income effects, specifically the economic impact on businesses (defined as the total value of fiscal revenues and fewer variable costs). Costs for irrigation, feed (more stock purchases and use), crop protection (less spraying), fuel and contract labour (reduced diesel costs due to less mowing and maize chopping), and storage and delivery costs are some examples of variable costs (Reinhard et al., 2015).

In the southern sandy areas, the estimated overall economic impact of the drought is approximately €400/year/ha. Some farmers produce their food for their livestock, such as meat pig farmers. Those farmers are called fodder farmers. They have a potential economic impact of €720/year/ha. The crops also decrease by 5% less feed quality (Polman et al., 2019). An arable farmer collected less yield because of smaller-sized products.

The drought-related increase in feed costs is the main factor contributing to the decline in dairy farming income. Dairy revenue decreased by 1.5% in 2018, because of a 5.5% decrease in milk price and a 3% increase in milk products per cow. This was unrelated to the drought of 2018 (Polman et al., 2019). The decrease in dairy revenue was because of an immense increase in revenue in 2017 of 3.4%. In 2018, the milk prices decreased and makes it an average milk price year (Melkveebedrijf, 2020). Due to a decline in the price of milk, combined with rising costs, the average income per unpaid annual work unit in the dairy industry decreased from 4.000 to 3.000 euros (Reinhard, et al. 2015). The livestock farmer stated that he received less yield due to a lower quality of food for the dairy cattle. The drought caused the income of dairy farms with sandy soils to drop more drastically than farms with peatland and clay soils (Polman et al., 2019).

Due to the dry summer in 2018, the production per hectare of the majority of crops has decreased significantly, except for grains. Farmers stated that a drier year is exceptionally better than a normal year. On the free market, the poor production raises prices for field potatoes (+50%), and onions (+11%). In that same year, the price of sugar beetroot (-20%) fell short of the previous year because of an increase in the global supply of sugar (Polman et al., 2019). Forty per cent of the respondents describe that their actual yield improved in a drier year. The market prices will compensate for the quantity losses. They stated that:

"Drier years are often exceptional years. This depends on the market changes, the amount of precipitation and the quality of the soil. Overall, with a drier year, we often have a good and better year."

Another arable farmer achieved a balance between expenses and income. The investment in technology saves the crops from being destroyed. The investments are expensive, but by maintaining the crops the prices can be compensated. The farmers that increased their income used measurements, such as irrigation, (controlled) drainage, drip system, holding water in weirs with iron plates, and compost. Nevertheless, other farmers used the exact same measurements against drought, but still, the farmers received less yield. The dairy farmer used measurements for irrigation, holding water, and increasing the organic matter in the soil. The dairy farmer did not use other measurements for their land.

4.4 Robust, adaptive, and transformable farming system

Forty per cent of the respondents that received less income as an impact of drought on their farm, also found it difficult to bounce back after a period of drought. They got less yield and a lower quality of products. According to KNMI, drought will occur longer and more frequently in the upcoming years. Irrigation costs will increase, and therefore yield will decrease. In addition, the food quality will decrease due to limited water, which will lead to a smaller amount of the weight of the crops. If the quality of food is lower, the income will also reduce. Dairy farmers have an extra step in their process. The quality of food decreases, which influences the health of the cattle, and thus the decrease in milk (Polman et al., 2019).

Nevertheless, sixty per cent of the arable farmers said the opposite of their profitability. They stated that drought is more manageable than for instance flooding. Flooding causes rotting crops, and the farmers cannot sell those on the free market. Drought causes products to shrink, but the farmer can sell them again. Therefore, the farmer receives an income that could outweigh the extra irrigation costs. In a drier year, the profitability is the same or higher than in a normal year. The market prices will compensate for the extra costs of irrigation. The resilience to drought is due to the irrigation machines. The investment in irrigation techniques is expensive. The advantage is that they can decide when and where to use the method. Either they drive it to the field, when it is dry or leave the machine in the shed. The soil is then better for water infiltration and retention. Sandy soils are easy to work with than clay soils. Clay soils have a more moist, firm, and heavy structure than sandy soils (Heinen, et al., 2022). Irrigation technology helps with the growing of optimal crops. The farmer can decide when, and where to irrigate. If flooding takes place the area of crops is destroyed. The farmer has no income. This is not the case with drought if the irrigation techniques are being used. The crops suffer less from diseases, and thus the harvest is better. The quality of food is bigger than in other regions, so the price of the products is higher. The profitability then increases according to an arable farmer. For the interviewed farmers, it is easy to bounce back with the previous profitability after a period of drought.

In a like manner, the farmers stated how easy or difficult it is to bounce back to the current situation after a period of drought. All farmers stated that it is easy to bounce back. This is due to the irrigation techniques that are used to prevent an immense decrease in food quality. All farmers anticipated the drought with their equipment.

"We invest in irrigation techniques. This is an expensive investment. The advantage of an irrigation machine is that we can leave it in the shed when it is wet. Either we drive to the field when it is dry or leave the machine standing. In terms of soil preparation, we do not do anything different with wet or dry conditions. The soil just has to be good for infiltration and water retention. The resilience in the event of drought is due to the irrigation machines."

The farmers will suffer from drought without technology. It will take a year and a half to get back to the current situation, especially for livestock farmers. The food quality for dairy cows is lower, and the restocking of the food takes an entire year to grow. The irrigation technology ensures that the farmers can easily bounce back.

All farmers adapt by using irrigation technology in response to drought. Further, retaining water is a crucial step for the farmers and using compost. Retaining water consists of iron plates in ditches and manage weirs by themselves. The technique of precision farming is not used often, as well as (controlled) drainage, drip hoses, smaller reels, and leaf protection. Farmers also think about technologies for the future, such as using controlled drainage or drip irrigation. They are looking for opportunities to produce higher-quality products, such as new irrigation technologies and data management. Data management contains technologies, such as satellite data, GPS systems, remote control, and monitoring to remove overlap from the irrigation machines. In some ways, investing in new practices and technology as well as being open-minded can improve adaptability (Reidsma et al., 2017).

The technologies used in response to drought were all implemented quickly or were already implemented according to the farmers. Most of the technologies were implemented after a dry year, like 2018. This took between 1.5 to 3 years. Irrigation techniques were already implemented due to the watering of the crops.

The farmers encountered problems with implementing techniques. The problem all farmers endure is the labour with implementing these technologies. Furthermore, water availability, regulations from the water board, and accuracy and the capacity of irrigation are problems that occur within their farm. According to Joris Baecke from ZLTO, farmers deal with contradictory legislation. Certain politicians want farmers to stop using crop protection. At the same time, farmers are advised to plough as little as possible in order to reduce CO_2 emissions. If farmers do not plough, weeds grow, and they have to use crop protection (Baecke & Nationale ombudsman, 2019).

On the other hand, other technologies have effortlessly been changed, such as retaining water, spreading compost and adjustments on land like laying underground pipes. The farmers also stated that it is normal to implement such techniques due to the drought, otherwise, we cannot compete with other farmers and the market.

Transformability is the ability to drastically alter the internal structure of the farming system. These improvements may also involve adjustments to how the farming system operates (Meuwissen et al., 2019). With this knowledge, precision farming is one way of transforming the farming system. According to Casto. (2021), new levels of data and controls are becoming possible because of the Internet of Things (LoT). It is anticipated that it will be an effective driver for the transformation of farming into creative networks of interconnected objects. According to Bos et al. (2018), turning it into an object is a transformative effect on a system and the subjectivity of farmers. It is a process in which adjustments are made to facilitate the needs of the farmers through the system (Bos et al., 2018). LoT will significantly increase production and sustainability in agriculture. However, for the farmer to put all of this data to use and participate in this transformation, the information must be gathered, shared, stored, retrieved, and analysed. This requires current knowledge and perceptions (Casto et al., 2021).

The results of a resilience assessment in France indicated that investing in innovative technologies and practices can be considered a form of adaptability or transformability. It depends on the degree of technological innovation (Reidsma et al., 2017). It makes it difficult to conclude if a technology links to adaptability or transformability. However, technology can be considered transformable if it entails a new method of production and would lead to the development of brand-new professions and abilities. Practices that reduce droughts are often long-term adjustments to the system. The technologies prevent the impact of drought, such as ecological engineering. They can limit the transformability of the system, such as increasing organic matter in the soil. This takes five to seven years to build a per cent of organic matter (Farmprogress, 2023).

The farmers stated that irrigation technologies, precision farming, and upgrading water retentive capacity changed the internal structure of their farms. However, from the literature review irrigation technologies and upgrading water retentive capacity shows that this is more related to adaptability. Precision farming requires internal structure for both the farm and the attitude of the farmer. The farmer participates and develops new abilities through their decision-making processes. Precision farming is a way of transform the farm.

5. Discussion

In this section, the strengths, and weaknesses of the resilience framework of farming systems are described. Further, the results of resilience are compared with the case study Veenkoloniën by Reidsma et al. (2017). The limitations of this research and further research are also defined.

Resilience framework

The resilience framework is essential for farming systems to be sustainable and adaptable to face diverse difficulties and uncertainties. One strength of the resilience framework by Meuwissen et al. (2019) is the complete evaluation. The framework offers a methodical way to evaluate resilience's various elements, such as ecological, social, economic, and institutional elements. It makes it possible to evaluate the farming system as a whole, considering both its internal- and external environment. Another strength is the detection of vulnerabilities, and challenges within the farming system. By proactive identifying potential risks, such as climate change impacts, or market fluctuations, the farmer can implement measures to mitigate those risks. However, the resilience framework also has weaknesses. It can take a lot of time and resources to complete because significant data gathering, analysis, and participation by stakeholders are needed. Small-scale farms or organisations with limited resources could find it challenging to spend the required time, knowledge, and resources to conduct a complete examination. The restriction might prevent the framework from being widely used and put into practice, especially in environments with few resources. Finally, the term resilience is complex, which can lead to an incomplete understanding. Resilience is dynamic, making it challenging to include all elements inside a framework. Because of this, some aspects of resilience may be neglected, which limits the thoroughness of the evaluation and the efficiency of the resilience-building techniques.

Reusel compared to Veenkoloniën

The resilience framework was used for the case study in Reusel and in Veenkoloniën. Reusel is in the southern part of the Netherlands. The farming system is diverse, with a mix of intensive livestock and arable farming. The farmers focus on challenges, such as irrigation, and nutrient balance related to drought. The region has implemented various measures, like precision farming, and irrigation strategies to adapt or transform the farm. The resilience of Reusel is moderate. Veenkoloniën is located in the northeastern part of the country. It is known for its intensive arable farming with a focus on starch potatoes, sugar beets and wheat. The main challenges were extreme weather events, low margins of public distrust and constantly changing policies and regulations. Current policy systems concentrate on robustness while ignoring transformability. The resilience of the Veenkoloniën is low to moderate (Reidsma et al., 2017).

Both case studies feature specific challenges for their regions, such as maintaining natural resources (soil) in Veenkoloniën, and water management in Reusel. They shared themes in terms of adaptation, diversification, and cooperation between stakeholders. In order to increase resilience, both regions stress the significance of using sustainable land management techniques and looking into alternative crops or production methods. They also emphasise the value of cooperation between arable and dairy farmers. The contrast between the two case studies is the geographic and environmental factors. The Veenkoloniën are characterized by the soil composition and peat subsidence, which limits the production capacity of goods. Reusel is influenced by specific hydrological conditions. The freshwater for irrigation comes from groundwater. Due to the dominated sandy soils, there is a lack of water retention capacity. As a result, the farmer's production of goods suffers from a water shortage on their land during drought. Another difference is the resilience strategies. The Veenkoloniën were focused on growing new crops, investing in solar panels, and sharing agricultural education about farming (Reidsma et al., 2017). In Reusel, precision farming and irrigation technology are implemented to address the drought challenge. The resilience strategies are unique to each region based on their main challenge. The farmers and the government have to cooperate with each together to see what needs to be accomplished by looking at the main problem. A single national policy on drought is not an optimal solution for both farmers with sandy soils and clay soils.

Research limitations

There are several limitations when conducting interviews as a methodology. The number of respondents in the interviews may be limited. A small sample size may not include the diversity of perspectives and experiences within the farming system. The results could be generalized due to overrepresented or underrepresented respondents. This can affect resilience. Livestock farms experience a heavier impact from drought than arable farmers. In addition, the farm size in terms of hectares for both arable and dairy farms was triple the amount of the average size, which is 59 ha in 2022 (Wageningen Economic Research, 2022). The average farm size of arable farmers in Reusel is above 59 ha. This also applies to the size of dairy farmers. According to Wageningen Economic Research (2022), the average dairy farm on sandy soils is 55 ha in 2021. The size of dairy farms is triple the amount of the average size on sandy soils in 2021. However, the statistics of the Central Bureau of Statistics (CBS) show that larger companies grow faster than smaller companies. The larger arable and dairy farms earn more, which gives room for investment and expansion in response to drought. Companies often do not apply major measures because they have no prospects for the future. The farmer can also orient themselves on the development of their business (Vergaderboer, 2009). In addition, it is often more difficult for smaller companies to find a successor than a larger farm, according to the statistics of the CBS (Van Rossum, 2021).

Conducting interviews is also time-consuming and resource intensive. The available time, and budget are limited. The interviews were held through MS Teams. Conducting interviews through MS Teams impacted the depth of data collection. To make the most use of the interview, it is crucial to prepare the interview process and figure out following-up questions based on literature review. The conducting of interviews coincided with the literature review. From the literature research, questions arise aimed at profitability. The depth of profitability was not further questioned by the farmers during the interviews. They only indicated if they received an increase or decrease in profitability during a drought. This could be one of the focus points for further research.

Further research

During the interviews, several challenges emerged that have a bigger impact on the farmer's profitability. These challenges were related to flooding, and governance. The challenges influence the general resilience of the farming system. The governance plays a crucial role in supporting resilience within the farming system. The farming system can be more resilient through participatory strategies that involve farmers in the development of policies and decision-making processes. Further research on governance within the resilience framework can provide valuable insights into the institutional arrangement, policies, and decision-making processes. For example, multi-level governance. It analyses the interactions between local, regional, national, and international governance levels. Unique policy features can ensure that the resilience per farming system can increase by addressing the specific problems in that area.

6. Conclusion

The main research question of this research was: *"What is the resilience of the farming system in Reusel by looking at the environmental drought challenge?"* To answer this question, four sub-questions were made by focusing on the farming system, drought development, influence of drought and robustness, adaptability, and transformability. The main question was answered with the aid of a literature review and farmers of the area in Reusel.

The farming system in Reusel is based on intensive arable farming as well as livestock farming. Reusel is defined by sandy soils, and the cohesion between livestock and arable farming. The arable production is based on the primary good potatoes, although sugar beets, onion, corn are also cultivated. The production from livestock is divided into dairy cattle and meat pigs. The cohesion between arable and livestock farming is important for the fertilisation of their ground and interaction of soil and crops. The production capacity is limited due to the soil type. Sandy soils have no adsorption capacity and therefore has a low moisture-binding capacity. This makes sand permeable to water, and thus drought occurs more in sandy area.

Drought is caused by lack of precipitation and/ or an increase in evaporation, which results in water shortage for plant growth, river run-off, and contamination. In the beginning of the drought season in 2023, the first months were wet. In June, the precipitation deficit and evaporation increased, leading to a dry period. The prediction for the next few weeks is still an increase in evaporation and precipitation deficit. Looking at the longer period, the KNMI created four climate scenarios based on temperature and airflow patterns. In all four scenarios, the evaporation increased between 3% to 7%. On the other hand, the amount of wetter days are slightly increasing by lower air pattern changes. The amount of wetter days decreases between 5.5% and 10% with higher air pattern changes. Another variable that is investigated with the KNMI'14 scenarios is drought. The average highest precipitation deficits during growing season are increasing in all four scenarios with 0.7% to 30%. The highest rainfall deficit exceeded once every ten years also rises to 300-330 millimetres. Drought will occur more frequently over time, due to the increase of evaporation and precipitation deficit.

Drought affects both financially and soil and water quality on the farming system. Sandy soils absorb water more difficult than clay soils in a drier period. This results in a decrease in groundwater levels, and the decline of soil moisture. Nutrients cannot be absorbed and are quickly washed out after precipitation. Therefore, the soil quality deteriorates. Nutrients ensure healthy soil life and the growth of crops. In order for plants to grow, many farmers irrigate water from ditches to their land. The ditches dry up faster, and the groundwater level drops even faster. According to the farmers, there is a shortage of fresh water. The crops do not grow optimally, and the quality deteriorates. The products become smaller and weight. The farmers receive a lower yield of approximately €400/year/ha for their deteriorated product. Dairy farmers suffer more from a decrease in yield due to the extra step by using their crop as a food source for livestock. However, the free market plays a role for the income for the farmers. On the free market, prices for products can rise, as in 2018 with an increase of 50% for potatoes and 11% for onions. Drier years can be exceptional better years. This can differ per farmer, due to the size of the farm or the applications to combat drought.

Robustness describes the extent to which the agricultural system experiences drought, and how farmers respond to it. It is divided into the current situation and the profitability for the farmers. After a period of drought, it is easy to bounce back for the farmers to the current situation. This is due to the investment of irrigation technology. Without the technology, it takes a full year to get back to the current situation. The opposite is the case with profitability. There are differences in the impact of drought on yield between farmers. Their yield can drop due to the decrease of food quality and the higher irrigation costs. However, farmers stated that farming is more manageable with drought. The profitability is greater than years without drought. With the aid of irrigation technology, retaining water, using compost, precision farming, and (controlled) drainage the profitability can increase. These technologies enable farmers to adapt to drought. One farmer implements more techniques than the other, but all farmers are working on measures against drought. The adaptability of the farmers is strong. The transformability of the farmers is low. Precision farming is a technology that made an intern structural change in the system. However, long-term technologies that reduce the impact of drought limit the transformation of the system. The farmers in Reusel did implement irrigation techniques, but did not make drastic changes in their farm, except precision farming.

Overall, the resilience of the farming system in Reusel is moderate. The farming system consists of intensive arable- and livestock. The main produced goods are potatoes, milk, and pork. The produced goods are grown on sandy soils, which are sensitive to drought. Now, precipitation deficit and evaporation are increasing, that leads to longer drier periods. The soil- and water quality are decreasing, which contribute to a nutrient deficiency for the growth of crops. The profitability of the farmers is lower. However, the implemented measurements maintain the growth of the crops. This leads to higher income for the farmers. The adaptability of the farmers is high. Nevertheless, the technology that is used in response to drought is not related to transformability. Farmers use technology to adapt to the drought. There is no change in the internal structure of the company, except for precision farming. Farmers will have to adapt or transform more in the future due to the increasing drought. It is important to look at the future drought, because the farmers in Reusel can take limited measures due to their soil type and freshwater source.

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Annex I: Interview questions – Resilience of the farming system in Reusel to drought.

General

- Proposal round
- Questions for recording conversation
- Results are displayed anonymously in the report
- Sensitive information is not shared, this will be discussed at the end

Introduction

1. How many years have you been running your own business?
2. What does your company fall under? (Livestock farms, greenhouse horticulture companies, arable farms, companies that grow in buildings)
    a. Livestock: What kind of livestock do you have?
    b. Arable farming/greenhouse horticulture: What kind of crops do you grow?
3. What is the total size of your farm?
4. What types of soil are on your land?
5. What do you expect from the succession of your company?

Farming system

Definition agricultural system is: "the core of the system are the farmers who produce the most important products in the region". This also includes other actors that mutually influence each other.

6. How do you define the agricultural system in Reusel?

The current challenges at your company

7. What do you think are the main challenges on your farm in terms of drought?
8. What do you think are the most important strategies for dealing with drought on your farm?

Impact drought on your company

9. What impact does drought have on your business from a financial perspective?
10. What impact does drought have on your farm in terms of soil and water quality?

Company resilience

Robustness:

11. How easy/difficult is it for your farm to bounce back to the current situation after a period of drought?
12. How easy / difficult is it for your farm to bounce back to current profitability after a period of drought?

Adaptability:

13. What new activities or technologies are you applying in response to drought?
14. How quickly have you adapted these activities or technologies?

Transformability:

15. What decisions have you made that resulted in a change in your business?
16. What problems do you encounter why reorganizing your company is difficult?
17. What are the changes you can easily implement for a transition at your company?

Closing

18. Do you have any further comments or additions for the study?

19. Which sensitive data should not be published?