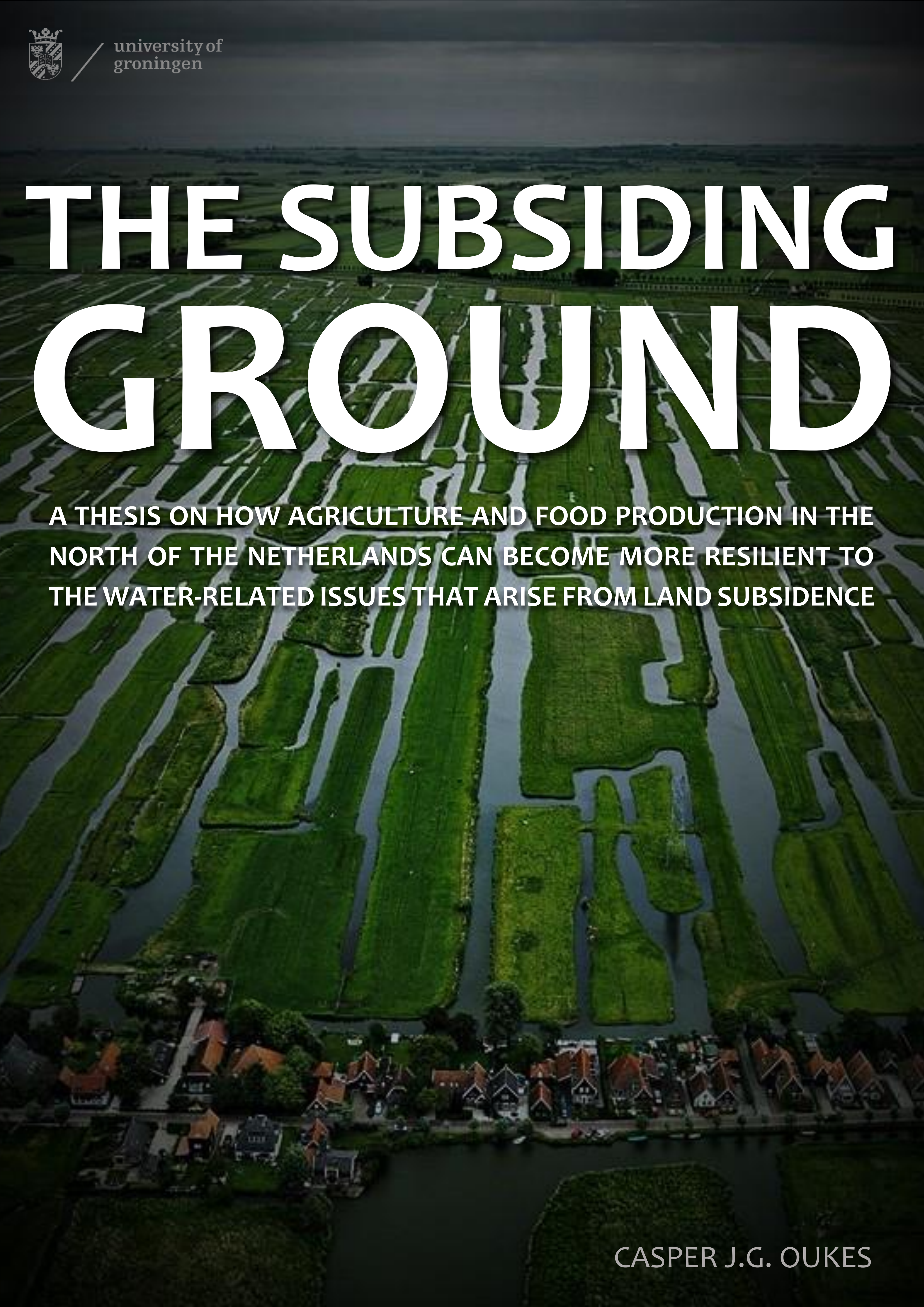

university of groningen

THE SUBSIDING GROUND

A THESIS ON HOW AGRICULTURE AND FOOD PRODUCTION IN THE NORTH OF THE NETHERLANDS CAN BECOME MORE RESILIENT TO THE WATER-RELATED ISSUES THAT ARISE FROM LAND SUBSIDENCE

CASPER J.G. OUKES

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Pexels (2017)

Abstract

Land subsidence is a phenomenon that can be found almost everywhere across the north of the Netherlands, resulting in water-related issues for the agricultural sector. Using a combination of primary- and secondary data research, this thesis scrutinizes what those issues are and which approaches, methods, or measures are used to deal with its effects on agriculture. By considering future prognoses of these problems and the implications that come along with climate change, the resilience of the current methods will be assessed. All of this is done as the greater aim and central question of this thesis is: How can agriculture and food production in the north of the Netherlands become more resilient to the water-related issues that arise from land subsidence?

By analysing scientific litarature, research reports, and by conducting interviews with experts on the topic of land subsidence, agriculture, and governance, this thesis finds out that roughly two main water-related issues arise from land subsidence, being: a direct, quantitative issue; as the distance between agricultural ground levels and the water table is reducing, resulting in wetter grounds, and the more indirect, qualitative issue of increased salinization. Historically, the main methods of dealing with these problems have been an increase in pumping and drainage capacity, fragmenting our water systems, and the flushing of salinized surface water with fresh water. However, all of these measures are to a large extend examples of reactive measures, and in some cases these measures even enhance the cause of the problem that it is trying to solve. Land subsidence- and climate change prognoses ask for more proactive and resilient methods to tackle these issues. The first steps to come to this is the acceptance and an increased awareness of the problem, as this is the starting point for anticipation. This thesis proposes a few methods to build on resilience, such as the prevention of further fragmentation of water systems, an increased focus on the retention and storage of (fresh) water, intrinsic changes in the methodology of farmers such as stimulating the amount of humus in agricultural grounds, area-specific prohibitions on ploughing, or preventing the use of heavy machinery (especially on wet grounds), and long term and more profound resilience-increasing methods such as crop transition or the re-division and re-allotment of agricultural land.

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1. Introduction

1.1 | BACKGROUND AND SOCIAL RELEVANCE

On the seventh of February 2017 an article on the Dutch news broadcaster NOS stated that the agriculture in the Noordoostpolder is threatened by land subsidence (NOS, 2017). Due to this land subsidence the ground level is approaching the water table level closer and closer, resulting in wetter grounds. In the coming years, this results in a higher chance of rotting decay for crops like seed potatoes, onions, and flower bulbs. It is an alarming situation and socially a very relevant topic, since land subsidence is a process that is very hard to bring to a stop, and a substantial amount of agricultural land in the Netherlands are subject to this problem (Kwakernaak, 2015). Currently, the prevailing method of regulating ground water levels proportional to land subsidence by draining superfluous water, does not seem to have eternal life. In Dutch water management in general, we currently see the paradigm shift from "fighting the water" towards "living with the water" (Restemeyer et al., 2015) in which we try to give water more space. Nevertheless, the application of drainage in order to create the most favourable conditions for agriculture is an example of a technical and 'hard' measure, which seems to contradict to this new paradigm. We can even question the sustainability of this activity, taking into account the water-related issues of the future resulting from land subsidence, but also from climate change, resulting in a changing precipitation pattern (Gregory, 2013) and an average sea level rise that can reach up to +0.4m by the year 2100 (IPCC, 2013). These physical developments ask for a different approach in water management in order to make food production and agriculture more resilient.

1.2 | THEORETICAL RELEVANCE

The theoretical relevance of this thesis can be found in the fact that it strives to complement, and fill the gaps in our present theoretical framework concerning this - as illustrated in the previous paragraph socially very relevant - topic. There has been much research on the topic of land subsidence in the Netherlands, the water-related effects this has on agriculture, and also about increasing resilience in water management, as will be illustrated in the *Theoretical framework*. However, there is still a theoretical gap in to what extent the resilience in agriculture and food production can be increased with regards to the water-related effects of land subsidence. Currently, the scientific articles upon this topic are mainly focussed on the larger scale concepts, paradigms and paradigm shifts, but the smaller scale methods and measures in order to increase resilience in agriculture are often underexposed. As this thesis addresses and emphasises this aspect, here the scientific, or theoretical relevance of this research can be found.

1.3 | RESEARCH PROBLEM

By setting out our current methods of protecting agricultural land against water, the resilience in our current approach can be assessed. This is done with the greater aim to scrutinize the possibilities of making agriculture and food production in the north of the Netherlands more resilient to the water-related issues that arise from land subsidence. This process, combined with the implications that come along with climate change asks for structural changes in Dutch agriculture and water management, as was illustrated in the paper of Ritzema & Stuyt (2015). The consequent research question for this thesis following from the research problem is therefore:

> *How can agriculture and food production in the north of the Netherlands become more resilient to the water-related issues that arise from land subsidence?*

There are three secondary questions that will lead to this central research problem.

1. First, there needs to be a clear overview of the problem of land subsidence on agriculture. What is the size and scope of the problem? Where can it be found and to which water-related issues does it lead for agriculture? The subsequent secondary question following from this is: *What are the size, scope and effects of the problem of land subsidence, and where can they be found?*
2. A closer look is needed on how land subsidence is currently dealt with in agriculture. What are our current methods in dealing with the water-related issues? It leads to the following secondary question: *What are our current methods in dealing with land subsidence and its water-related issues for agriculture?*
3. If this knowledge is gathered, the resilience and sustainability of our current methods can be assessed with the use of the secondary question: *How resilient are our current methods in dealing with the water-related issues of land subsidence?*
4. From here there can be worked towards the conclusion of this thesis. What can be done to diminish the effects of land subsidence for agriculture? How can agriculture and food production become more resilient? These topics will be touched upon by answering the main question of this thesis: *How can agriculture and food production in the north of the Netherlands become more resilient to the water-related issues that arise from land subsidence?*

1.4 | HYPOTHESES

The hypotheses that will be tested throughout this thesis can easily be derived from the *Research problem* above. Here, the hypotheses can be seen as “a testable research statement or question for investigation, often linking observation to an assumed cause or set of causes” (Clifford et al., 2013, p.531). These hypotheses are:

- Land subsidence is a problem for Dutch agriculture (1).
- We currently use ground water regulation to cope with the water-related issues arising from land subsidence (2).
- Ground water regulation is not a sustainable and resilient method and does not go along with current paradigm shifts (3).
- By using methods, strategies and techniques, the effects of land subsidence on agriculture can be diminished, and food production can become more resilient (4).

1.5 | READING GUIDE

After concluding this introductory chapter the theoretical framework of this thesis will be built, in which the most important concepts, theories and paradigms are scrutinized. In the subsequent chapter the methodology of the research behind this thesis is explained, containing information on the research method, the data collection- and data analysis process and ethical considerations. The penultimate chapter brings the results which discusses the data in the context of the theory. Main findings are given, just as a critical reflection upon this thesis. Both the secondary questions as well as the main question of this thesis will briefly be summarized and answered in the conclusion, followed by a policy advise which results from the interpretation of the obtained knowledge.

2. Theoretical Framework

2.1 | SCOPE OF THE PROBLEM

The severity of the problem of land subsidence differs locally, just as the water-related effects. There are a lot of important determining factors for this, such as: soil type, land subsidence type (natural or anthropogenic), influencing external factors such as global warming, and also the type of land-use above the land that is subsiding. The lower the ground water levels are - especially in summer - the more rapid land subsidence proceeds due to processes of settlement and oxidization (Galloway et al., 2016). Agriculture is a good example of a land-use that is heavily affected by this phenomenon (Kwakernaak, 2015). Land subsidence causes the ground level to approach the ground water level, resulting in wetter grounds. Certain crops, such as onions and potatoes flourish bad in wet grounds and can even start to rot. The following parts of *Chapter 2* will touch upon most of these influencing factors.

2.2 | LAND SUBSIDENCE

Land subsidence is a global phenomenon and the continuing development and extraction of both land and water resources affects an increasing amount of regions worldwide with land subsidence (Galloway et al., 2016). This continuing process is therefore especially present at the most intensely used areas of the planet: the coastal areas and river deltas (Higgins, 2016). The Netherlands forms no exception to this and land subsidence is a problem that has been known for quite some time, affecting a large part of the country. A large number of scientific articles have been published about the nature of it and its effects. Roughly two causes of land subsidence can be distinguished:

Natural land subsidence is in a lot of cases caused by geological or soil physical processes such as the maturing or consolidation (subsidence caused by shrinking of the soil due to the own weight of the ground), settlement (subsidence due to the draining of ground water), or oxidization of certain soil types such as clay or peat (Kwakernaak, 2015). Furthermore isostatic adjustment, which is the “viscoelastic response of the Earth’s crust under a change in the weight of overlying material such as water, sediment or ice” (Higgins, 2016, p.590), can cause a rise or subsidence of land.

Anthropogenic land subsidence is mostly caused by mining for natural resources, such as the extraction of salt or gas out of the Earth’s layers (Kwakernaak, 2015). Next to this, some types of natural land subsidence processes are directly influenced by anthropogenic activities. A good example which illustrates this is the drainage of peat lands to cultivate them as agricultural lands; a broad spread method applied to make agriculture possible in a large part of the Netherlands over time. These drained peatlands stop the growth and accumulation of new peat, next to the fact that the lowered water table causes additional oxidation of the peat. To put it short: surface-water drainage leads to land subsidence (Galloway et al., 2016).

The combination of this natural and anthropogenic land subsidence next to external influential factors such as climate change will cause problems for the Netherlands in the years to come. According to prognoses, in some parts of the Netherlands the land subsidence can exceed -150 centimetres by the year 2100, in relation to 2010, as shown in *figure 1*.

2.3 | CLIMATE CHANGE

As briefly mentioned in the previous section as well as illustrated in *figure 1*, climate change can have an accelerating effect on natural land subsidence (Kwakernaak, 2015). Indirectly, global warming influences isostatic adjustments due to the melting of ice sheets. Furthermore it influences the amount of precipitation resulting in wetter periods, but also in droughts (Galloway et al., 2016). The Royal Meteorological Institute of the Netherlands predicts in their ‘WH climate scenario’ a 23% decrease in rainfall in the summer season, as well as an increased water evaporation of 15% in the summer season (KNMI, 2014). This combination of decreased precipitation and increased evaporation may be of critical influence for land subsidence as it leads to lower water tables resulting in settlement and oxidation of organic soils and thus further land subsidence (Galloway et al., 2016).

A closer look at the agricultural sector shows that this land subsidence reduces the distance between the ground level of the fields and the water table, increasing the chances of rotting of crops. The implications of climate change for agriculture are therefore not only periods with a shortage of precipitation, but also the periods with significant increases of precipitation as they will lead to more frequent agricultural problems, since there is simply less space for water to infiltrate into the soil (Ritzema & Stuyt, 2015).

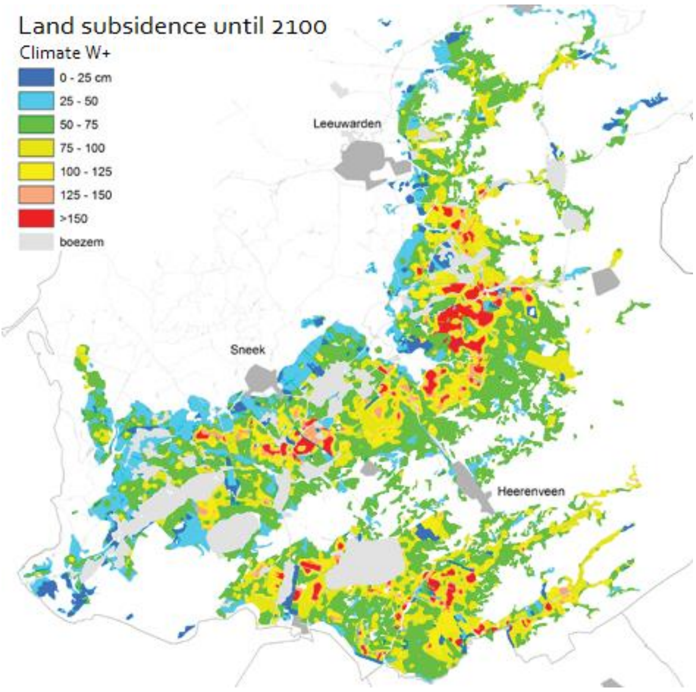

Figure 1: Land subsidence until 2100 in Het Veenweidegebied (Friesland), with a W+ climate scenario (Kwakernaak, 2015)

2.4 | RESILIENCE IN WATER MANAGEMENT

The previously cited articles about land subsidence and its effects for agriculture all "highlight the importance of improved understanding of subsidence processes and the hydrogeology and hydrology of the affected groundwater flow systems to reduce subsidence and the related geohazards" (Galloway et al., 2016, p.548).

Over time, and still today, a common method to avoid the water-related issues that arise from land subsidence is by applying drainage and pumping water away to lower the water tables proportional to land subsidence. Nevertheless, Ritzema & Stuyt (2015) state that currently a paradigm shift in regulating ground water levels can be observed. After the second World War, agriculture intensified and Dutch agriculture was mainly focused on creating the most favourable conditions for crops to grow by regulating the ground water level in order to get the best harvests. In 2008 the Delta Committee agreed on a paradigm shift. "Instead of increasing pumping and drainage capacities further and further, the focus has been shifted to control drainage in a three-step approach of decreasing priority: (1) retention of excess rainfall in the soil, (2) storage of remaining excess water in the field or the (field) drainage system and (3) controlled removal. The overall aims are to reduce peak discharges in periods of rainfall excess […] and to store extra water for periods of water stress" (Ritzema & Stuyt, 2015, p.82). This approach shows much resemblance to the three-step approach we can see in the Dutch water management in general;

Over the years, the Dutch water system was developed in such a way that it was able to drain surpluses of water as fast as possible, as these surpluses could form - and most certainly for agriculture - a burden quite easily. Since the last 25 years, the functioning of this model was debated a lot, especially since the near-floods of 1993 and 1995. From that moment onwards a movement more and more towards the three-step approach of '*retention - storage - removal*' can be observed (Hoekstra & Nijburg, 2009).

This three-step approach, as well as the one described by Ritzema & Stuyt (2015) can be seen as a move towards more water resilience in Dutch water management. There is little consensus in the actual meaning of the word 'resilience', and many definitions apply to the same term (Norris et al., 2008). "Social researchers have, nevertheless, sought to apply the term to social settings in an attempt to evaluate how individuals, communities and societies build capacity to adapt to shock, stress, disturbance and disaster" (Smith & Lawrence, 2014, p.2). Restemeyer et al. (2015) defines 'resilience' along the principles of robustness, adaptability and transformability as set out by Galderisi et al. (2010). In short, these three principles can be described as:

- Robustness: "means that a city has to be strong to withstand a flood event, for example by building and maintaining dikes, sluices and storm surge barriers". (Restemeyer et al., 2015, p.47);
- Adaptability: "implies that the hinterland is adjusted to flooding so that a flood event may come without leaving substantial damage". (Restemeyer et al., 2015, p.47).
- And transformability, which "can be interpreted as the capacity of a city to make the often demanded shift from 'fighting the water' to 'living with the water". (Restemeyer et al., 2015, p.47).

Gersonius et al. (2015, p.201) describes resilience as "the ability to remain functioning under a range of hazard magnitudes". This definition resembles the one used in the article of Vis et al. (2003, p.34) which state that the term 'resilience' can be used to describe "a tendency to stability and resistance to perturbation". Furthermore, in describing resilience, the article of Restemeyer et al. (2015) stresses the importance of the resistance-resilience dichotomy: a problem that the author observes often in flood risk management, as literature commonly differentiates those two terms, even though they are not clear opposites (Restemeyer et al., 2015).

Resilience in water management is a very relevant topic as the stress in the interaction between people and water is growing. Not only because the urban population keeps growing (especially in coastal zones), but also because of the absence of conscientious and adequate urban planning (Zevenbergen et al., 2008). On top of this, the economic crisis has resulted in fewer private flooding adaptation measures (Gersonius et al., 2015). All of these factors enhance the importance of resilience. Both Vis et al. (2003) and Restemeyer et al. (2015) make the link between 'resilience' and the paradigm shift that we currently observe in Dutch water management, and shortly mentioned in *chapter 1.1* We move from "fighting the water" with 'hard measures' such as dykes and water regulation by pumping it away, to "living with the water" by giving it more space. This contemporary paradigm and strategy was largely expressed in the 2000's note '*Anders omgaan met water: waterbeleid in the 21e eeuw*' (Ministerie van Verkeer en Waterstaat, 2000). The main aim of this policy note was to address the impacts of climate change in water measures and management. Future predictions of more extreme draughts and wet periods, proceeding land subsidence, and a rising sea level were linked to the new paradigm of giving water more space in "living with the water" (Woltjer et al., 2014).

Here, the academic relevance of this thesis is stressed once more, as a large question remains: to what extend is Dutch agriculture moving along with all these paradigm shifts as described above, in relation to the water-related issues arising from land subsidence? Until recently "the solution to more excess water was to increase pumping capacity. Yet the combined problems of climate change, sea level rise, land subsidence, and urbanization require more structural changes in water management" (Ritzema & Stuyt, 2015, p.80).

2.5 | RESILIENCE IN FOOD PRODUCTION

Now that 'resilience in water management' is covered, it is important to make the connection to 'resilience in agriculture' as well. Because what does this actually imply? This connection between resilience on the one hand, and agriculture and food production on the other, was well made by the case study of Smith & Lawrence (2014) to the resilience of the community of Rockhampton in terms of food security during the flooding of 2011. In this sense, 'community resilience' is a real process and not merely an outcome (Norris et al., 2008) and can be seen as the ability of a community to work on the personal and collective capacity to respond to these hazardous magnitudes in such a way that it both sustains and renews the community (Magis, 2010). "Resilient communities are those which, in facing vulnerability, further develop their resilience through responses to a crisis" (Smith & Lawrence, 2014, p.4). Therefore, increasing resilience in agriculture and food production is not just about "recommendations that may or may not be implemented in time for the next hazard event", but is really about the capacity of a community to 'transform' (Cutter et al., 2008, p.603).

In their research, Smith & Lawrence (2014) found out that Rockhampton was - due to various reasons - vulnerable to food insecurity. Basically, 'resilience in food production' means a responding to food insecurity, which can be a serious issue in times of 'hazard magnitudes' (Gersonius et al., 2015).

2.6 | THE HOLISTIC APPROACH

Water management and resilience encompass more sectors than just the agricultural. From a spatial perspective it presumably also touches multiple land-uses. Therefore an integrated approach is a prerequisite for water management. Since interests might be divergent in today's complex world, this integrated approach is not always an easy matter, as was pointed out by Restemeyer et al. (2015, p.55): "Moving towards a holistic resilience approach, based more on the ideas of adaptability and transformability, is not only difficult for public stakeholders, but also the broader population". An important aspect here is that there is a broad and high civil awareness and willingness to participate in the anticipation to problems. "Raising awareness among both public and well as private stakeholders is [...] key to making a shift to more resilient approaches [...] in the future" (Restemeyer et al., 2015, p.59). Both Restemeyer et al. (2015) and Gersonius et al. (2015) stress the importance of an integrated, holistic approach on flood risk management and resilience.

2.7 | CONCLUDING THE THEORETICAL FRAMEWORK

To put it in short, the most important theories and concepts that are relevant to this thesis are land subsidence, both natural and anthropogenic, the influence of climate change, and the combined effects on agriculture and food production. Two paradigm shifts have been observed: on a larger scale we move from "fighting the water" to "living with water" as described by Restemeyer et al. (2015), and on a smaller scale we have seen a shift in paradigm in ground water regulation from the creation of the most favourable conditions for agriculture towards the control of drainage in a three-step approach as described by Ritzema & Stuyt (2015). Both the paradigms of "living with water" and the three-step approach in ground water regulation can be linked to the term 'resilience' of which we found out that it is generally a long-term process and asks for a holistic, integrated approach (Restemeyer et al., 2015). This thesis will build upon this theoretical framework as it is of crucial importance for the data analysis.

The theoretical framework can be summarized well in the conceptual model (*figure 2*). This conceptual model is primarily a visual representation of the concepts and theories underpinning this thesis. It is built up from the three general secondary questions as pointed out in *chapter 1.3*, which lead to the central question of this thesis as we try to build on resilience.

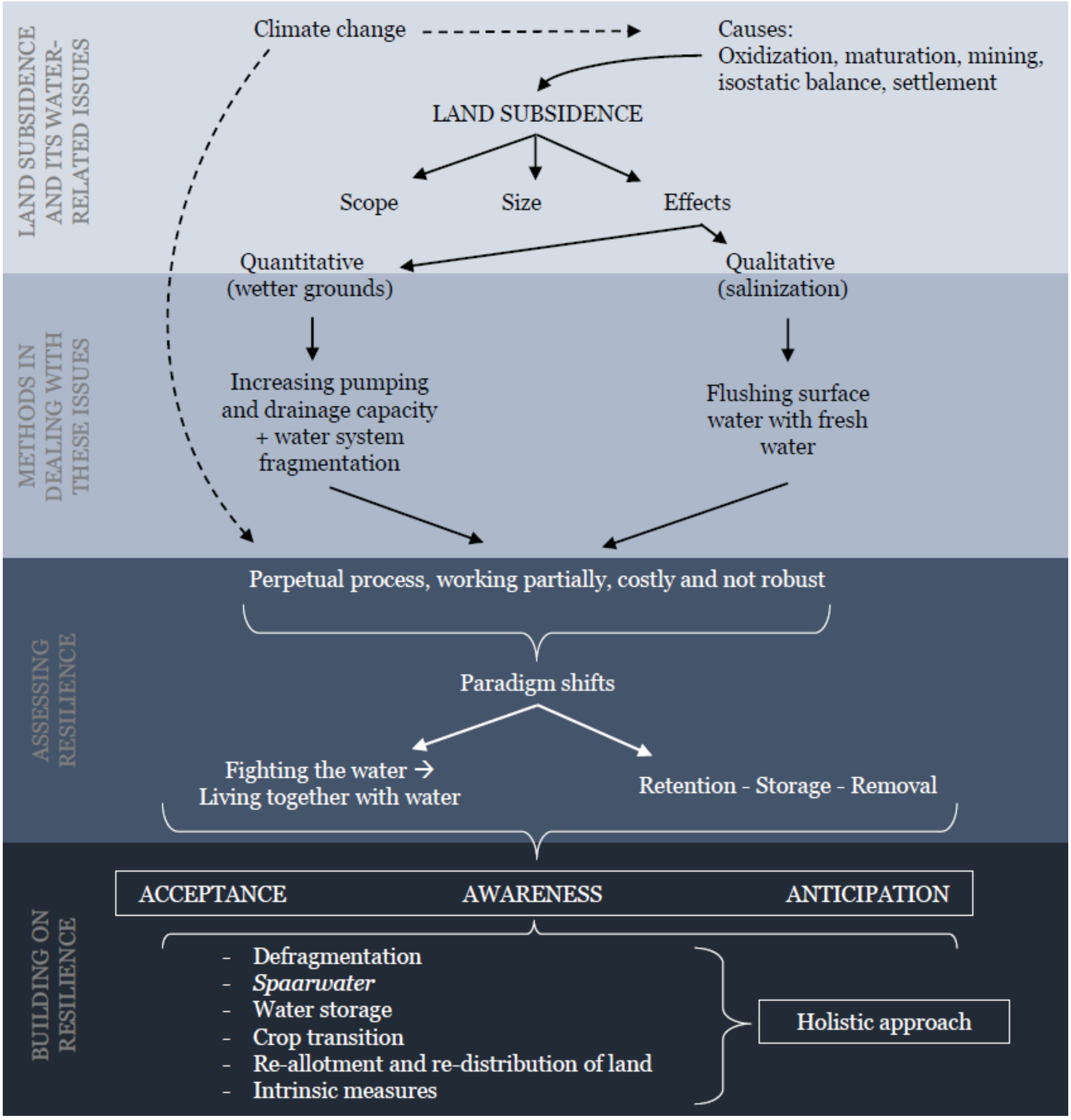

Figure 2: Conceptual model (own source)

3. Methodology

3.1 | RESEARCH METHOD

This thesis is based on a combination of primary and secondary data. To establish a good link between these two different kinds of data, the 'constant comparative method' was used. Data conducted from primary sources will be compared with other primary and secondary sources, and secondary data will be compared with other secondary, as well as primary data (O'Leary, 2004).

The secondary data will be provided by scientific articles and previously executed work, professional literature, but also elaborate research reports of contemporary projects on this topic, such as '*Vervolg fase 2: onderzoek bodemdaling Dongeradeel*' (2017) written by Witteveen+Bos in combination with Wetterskip Fryslân, or the '*Veenweidevisie*' (Provincie Fryslân, 2015).

Primary data for this research will be gathered by means of interviews. All interviews are held in Dutch and recorded, so a digital transcript can be made afterwards. With the use of interview coding and encryption, the answers will be analysed. The in-depth interviews are executed semi-structured, which means that, although there will be predetermined questions, the interview may unfold in a conversational way so certain - important - aspects can be explored further (Longhurst, 2013). An important aspect of the research method was the qualitative coding process. More information on this will be given in paragraph 3.3.

Figure 3 shows the *data processing scheme,* which has been made according to the conceptual model and is a visual representation of how and why the in-depth interviews will be analysed. It illustrates the four major parts with the corresponding questions of this thesis. The actual interview guides differ per interviewee and can be found in the attachment of this thesis.

The data collection method of interviewing was preferred over, for example, surveying, as land subsidence and its water-related issues for agriculture is quite an extensive topic based on facts and not so much on perception. In-depth knowledge of the topic (Longhurst, 2013) is prerequisite in order to give valuable information for this thesis. Therefore the data for this thesis will be based on scientific articles, reports and interviews with experts on the topic.

3.2 | DATA COLLECTION

The data collection process can be described in more detail if we look at the proposed questions:

1. *What are the size, scope, and effects of the problem of land subsidence, and where can they be found?* - Some of the data that is needed for answering these questions is conducted from secondary data, for example the essay of Kwakernaak (2015), and the article of Ritzema & Stuyt (2015). Interviews provides the majority of information needed to answer this question.
2. *What are our current methods in dealing with land subsidence and its water-related issues for agriculture?* - The main data source for answering this question comes from the working field, for example from interviews with people from district water boards of the north of the Netherlands.
3. *How resilient are our current methods in dealing with land subsidence and its effects for agriculture?* - There will be investigated if these current methods go in hand with contemporary paradigm shifts in Dutch water management as described by Woltjer et al. (2015), and by Ritzema & Stuyt (2015). Therefore, secondary data from literature is very important in answering this secondary question. Complementary information is derived from interviews.
4. *How can agriculture and food production become more resilient to the water-related issues that arise from land subsidence?* - The main source of information for this question is derived from interviews with experts from for example water boards or farmers (organizations).

To put it short: both primary data, as well as secondary data will be needed to answer the questions. Secondary data will be mainly used for concept definitions and large scale influential processes, such as climate change, land subsidence, paradigm shifts in water management and the concept of 'resilience'. Primary data will be gathered during in-depth interviews with various stakeholders and organizations, to get an insight in different viewpoints, information, processes and facts. The interviewees that participated in this thesis are:

- Maarten Jan Bijl; senior planner and coordinator of land subsidence for the water board of the province of Friesland: Wetterskip Fryslân. He is closely involved in the current situation of Dongeradeel, where the research report of Witteveen+Bos (2017) is about.
- Bert van Kalsbeek; senior planner and coordinator of land subsidence within Wetterskip Fryslân. Also closely involved in the situation in Dongeradeel.
- Ton Leijten; the '*Heemraad'* and therefore part of the executive committee of the water board Zuiderzeeland and a farmer in the Noordoostpolder.
- Rob Nieuwenhuis, senior policy advisor and policymaker within the department Strategy & Development, at the water board Zuiderzeeland.
- Berry Schuten, project manager and coordinator of land subsidence of the water board Noorderzijlvest which is in charge of a large part of the province of Groningen.
- Feike Wouda, policymaker Spatial Planning within the agricultural stakeholder organization LTO Noord which was closely involved in developing the '*Veenweidevisie*' (Provincie Fryslân, 2015).

3.3 | DATA ANALYSIS

The interviews will be analysed using qualitative coding. "A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based visual data" (Saldana, 2016, p.4) Coding helps to identify patterns and categories out of the interviews (Cope, 2013). Strauss (1987) identified tree different types of coding: open coding, axial coding, and selective coding. Open coding means that during the analysis of the interviews, certain code words will form as they'll be reoccurring during the interviews. In fact, this is a very unrestricted way of coding (Straus, 1987). Axial coding on the other hand proceeds along key categories, and can very well be combined with open coding (Straus, 1987).

This thesis will use a combination of both open coding, as well as axial coding, as the four major parts of the thesis as described above will function as key categories, and are illustrated in my coding table (*Table 1*) by using four different colours. From here, open coding took place, as from within the four part of the thesis, certain important concepts and theories reoccurred, and were therefore turned into a code.

What are the size, scope and effects of the problem of land subsidence, and where can it be found?

- Land subsidence prognoses
- Location
- Paradigm shift
- Scope of the problem
- Water-related effects
- Climate change
- Mining
- Oxidization
- Maturation
- Isostatic subsidence
- Settlement
- Mining

What are our current methods in dealing with land subsidence and its water-related issues for agriculture?

- Spaarwater
- Scale size of water level boxes
- Flushing brooks
- Groundwater regulation
- Increasing awareness
- Acceptance

How resilient are our current methods in dealing with land subsidence and its effects for agriculture?

- Expensive
- Perpetual process
- Unsustainable
- No alternatives

How can agriculture become more resilient against the water-related issues that come with land subsidence?

- Retain fresh water, salinization drainage
- Crop transition
- Re-division of land
- Stakeholder cooperation: holistic approach
- Water storage
- Multi-combined land use
- Monetarizing CO^2 emission

Table 1: Coding table (own source)

3.4 | DATA PROCESSING SCHEME

This data processing scheme as is shown in *figure 3* illustrates the four parts of this thesis, which can be connected to the *Conceptual model* (*figure 2*). Central aim of this scheme is to link the research question to the data collection and the data analysis.

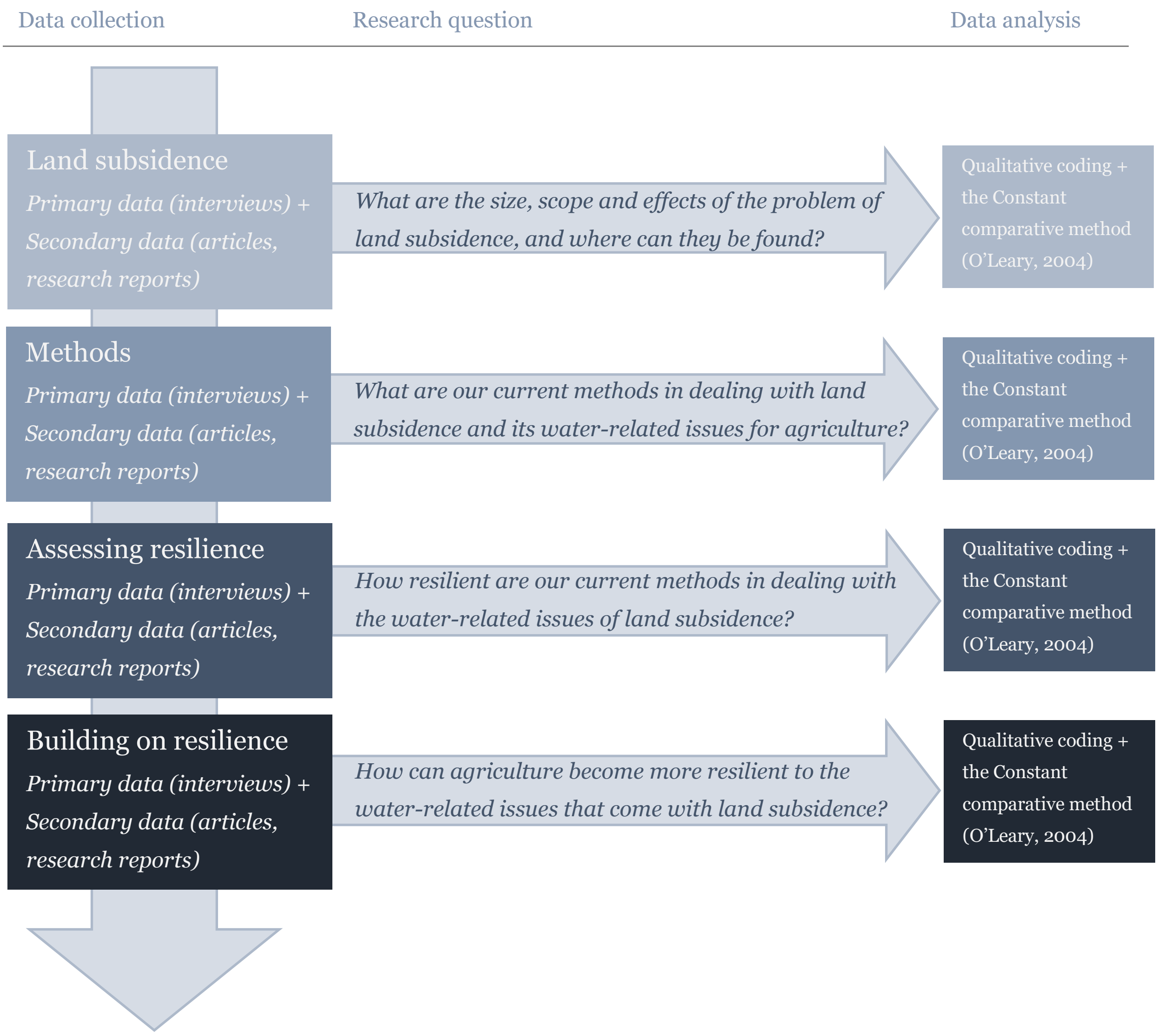

Figure 3: Data processing scheme (own source)

3.5 | ETHICAL CONSIDERATIONS

During the process of gathering both primary and secondary data, but in general throughout the entire research, ethical considerations are made. The principles of ethical behaviour will be taken into account as described by Iain Hay (2013): justice, beneficence, non-maleficence, and respect. Consent, confidentiality, harm, cultural awareness, and dissemination of results and feedback to participants all will be taken into consideration before, during and after the research (Hay, 2013).

Before and after the interviews, the interviewees are notified of the fact that their information and statements are treated scientific and ethically correct, next to the fact that they were allowed to withdraw themselves or their statements from this thesis during and after the interview. Permission to use their names and citations in this thesis was given upon request in the finalizing stages of writing the thesis. All of this was done as anonymity and confidentially are two serious ethical aspects (Longhurst, 2013).

4. Results & Discussion

4.1 | LAND SUBSIDENCE AND ITS WATER-RELATED ISSUES

A lot of agricultural land in the North of the Netherlands is subject to subsidence (TNO, 2006). The actual cause of this subsidence varies from place to place. Roughly five different causes can be distinguished: oxidation, settlement, maturation or consolidation, the natural subsidence of the North of the Netherlands due to the isostatic balance, and mining for natural resources (Bijl, Interview, 2017). A clear distinction between natural processes and anthropogenic processes can be seen, as described by Galloway et al. (2016). Especially for the natural processes, the soil type is a crucial variable that determines what the predominant type of land subsidence is and therefore as well what the scope of the problem is. To illustrate this, four areas will be described in more detail below, as these four areas and their underlying causes form a representative view of the problems perceived throughout the north of the Netherlands.

A. *Dongeradeel* is a region in the north of the province of Friesland, which has to deal with a total land subsidence of approximately 40 centimetres by 2050 (TNO, 2006). The predominant cause of land subsidence is the mining of natural gas by the NAM (Van Kalsbeek, Interview, 2017); around 20-25 centimeters of this total subsidence is caused by the extraction of gas (Witteveen+Bos, 2017).

B. Total land subsidence prognoses for the region north and east of the city of Groningen exceed 60 centimetres by 2050 (TNO, 2006). Approximately 45 centimetres of this total subsidence can be assigned to the anthropogenic cause of mining of gas by the NAM (Commissie Bodemdaling, 2017) (NAM, 2015).

C. *Het Veenweidegebied* is a large area in the province of Friesland. Here, the main cause of land subsidence is oxidizing and settlement of peat (Wouda, Interview, 2017). Even though these are examples of natural subsidence processes, Galloway et al. (2016) illustrates how anthropogenic interference of the land, such as agriculture, can accelerate this land subsidence. Current prognoses of the land subsidence of *Het Veenweidegebied* are around 40-60 centimetres until 2050 (TNO, 2006).

D. Ever since the *Noordoostpolder* was created in 1942, it has been subject to natural land subsidence processes of settlement and consolidation. However, currently the most problems regarding this theme arise from the oxidizing and settlement of relatively small peat layers. Prognoses of the total land subsidence in these places can reach up to 40 centimetres by 2050 (TNO, 2006). Currently, in some places, the land is subsiding with almost two centimetres a year (Nieuwenhuis, Interview, 2017). The problems in this area formed the basis of the NOS article (2017) *'Bodemdaling bedreigt akkerbouw Noordoostpolder'* as was mentioned in the introduction of this thesis.

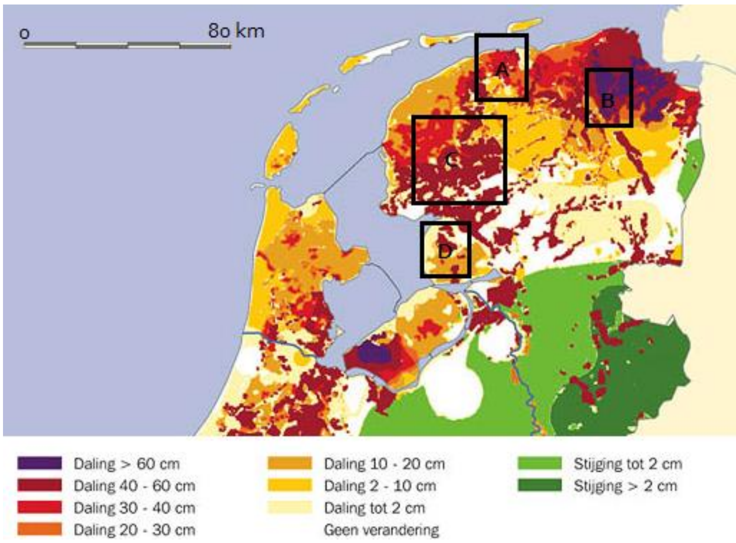

Figure 4: Expected anthropogenic and natural land rise and subsidence until 2050 (TNO, 2006)

Although the cause of land subsidence might be different from place to place, for agriculture it results into the same problems. Roughly two water-related issues can be distinguished:

The most direct impact of land subsidence is a water-quantitative problem, as agricultural fields are approaching the ground water table, which results in wetter fields. This causes a lot of problems for the farmers as the yields become smaller, the fields are less accessible, and the farmer is obliged to start later in the season with sowing and allowing cattle to go outside (Wouda, Interview, 2017). This reduction of space between the ground water level and the field level also means that the infiltration buffer for rainwater becomes smaller. During periods of intense precipitation the water level will be in the rhizosphere much quicker, resulting in a higher chance of rotting of crop roots (Nieuwenhuis, Interview, 2017). This is an alarming situation as the Netherlands will be subject to more periods of intense precipitation in the future, due to climate change (KNMI, 2014). As stated by Kwakernaak (2015), climate change can also have an accelerating effect on the actual cause of natural land subsidence. This is especially the case for the oxidation of peat which we can more or less see as a biological process, and these proceed faster in warmer conditions (Nieuwenhuis, Interview, 2017).

The second problem of land subsidence for agriculture is more a water-qualitative problem, and more indirect. As can be seen in the next section, the main approach in dealing with the water-quantitative problem as illustrated above, is by draining water away to lower the ground water level proportional to the land subsidence. However by doing this, salinization increases (Witteveen+Bos, 2017). The water level in the coastal polders is lower than the adjacent sea level, and by draining water away this difference in water level increases. The higher sea level pushes by pressure salt through the soil layers upwards. Especially the coastal regions of *Friesland* struggle with this problem, as a lot of crops do not thrive well in salty conditions (Bijl, Interview, 2017).

The main water-related issues that arise from land subsidence for agriculture are therefore that the grounds are becoming wetter, next to the fact that in some areas this may lead to an increase in salinization if no measures are taken. The scope of the problem differs per location, as there are a lot of important variables that determine what our possibilities are in dealing with these problems. These variables are not only the subsidence type, but also the composition of the ground, the land-use that should be served at the surface, the layout and arrangement within the different water systems, and the availability of funding to deal with the problem. All are influential factors that can determine which method is applied (Schuten, Interview, 2017).

4.2 | METHODS IN DEALING WITH THE EFFECTS OF LAND SUBSIDENCE FOR AGRICULTURE

Once the main quantitative water-related issue arising from land subsidence becomes so problematic that the agricultural sector encounters too much problems in order to function properly, over the years our main method was draining and pumping affluent water away. The most applied method to do this was by increasing pumping capacity, and by separating a part of the water system that encountered these problems from the rest of the water system. By doing this, district water boards were able to drain and regulate the water levels of the affected area without extensively changing the rest of the water system.

This is a method that is still used today, for example near *Tollebeek* in the *Noordoostpolder* (Nieuwenhuis, Interview, 2017). The same method was used recently by the district water board *Noorderzijlvest* due to the problems of land subsidence they encountered. *Figure 5* illustrates the current water system in their catchment area. Whereas this generally used to be one area with one common surface water level, as the water was able to flow by the natural forces of gravity from the land to the sea, it had to be divided into several smaller compartments, each with its own pump to cope with the severe land subsidence around the city of Groningen (Schuten, Interview, 2017). The province of *Friesland* on the other hand has a completely different water system as they have cut their water system up into hundreds of separate compartments, each with its own water table and pump (Nieuwenhuis, Interview, 2017), partly due to land subsidence. So over time - and still today - land subsidence is changing the water systems in the north of the Netherlands. However, this water system layout is also of great importance to the way future subsidence can be dealt with.

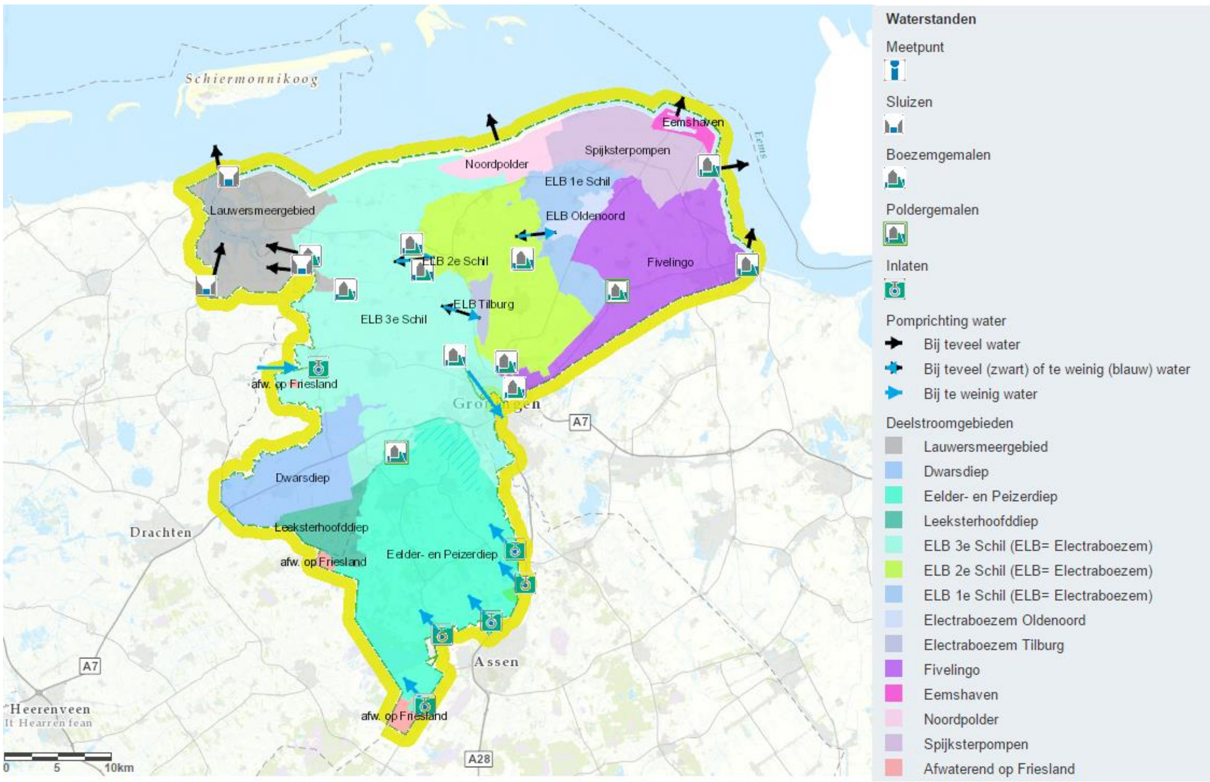

Figure 5: Substream areas in Northwest Groningen (Waterschap Noorderzijlvest, 2017).

There are fewer possible methods in dealing with the qualitative and indirect water-related issue of land subsidence: salinization. The main measure is flushing surface water surrounding the agricultural fields that suffer from salinized conditions with fresh water (Bijl, Interview, 2017).

4.3 | ACCESSING RESILIENCE

Chapter 2.4 described that there is little consensus about the meaning of the term 'resilience'. Nevertheless, for this thesis the definition given by Smith & Lawrence (2014, p.2) can be used. They described it as building on "the capacity to adapt to shock, stress, disturbance and disaster". So far we have seen that the main water-related issue of land subsidence is that agricultural fields are becoming wetter, and it has the side effect of increased salinization. The main methods to deal with these problems were illustrated above; ground water regulation and the flushing of surface water (Bijl, Interview, 2017). However, the chances on the occurrence of 'shock, stress, disturbance and disaster' (Smith & Lawrence, 2014) is growing due to the impact of climate change (Galloway et al., 2016). A critical view on the resilience of our current methods in dealing with these water-related issues is therefore more urgent than ever.

Ground water regulation is at present and in general done by increasing pumping capacity and separating specific area's that face the quantitative water-related issue of land subsidence, from the rest of the water system, and regulating this specific area separately from the rest. This method has the advantage that it enables district water boards to operate on a very detailed area-oriented manner. Both to drain affluent water away from parcels that encounter the most problems, but also put specific parcels under water, for example to delay peat oxidation (Wouda, Interview, 2017). However the resilience of this method can be questioned, as a fragmented water system actually has a reduced "ability to remain functioning under a range of hazardous magnitudes" (Gersonius et al., 2015, p.201). In this case periods of intense precipitation can be seen as a 'hazardous magnitude', A fragmented water system cannot cope with this as good as a larger 'universal' system with one common water level. When a considerable amount of precipitation falls over a fragmented compartment within a system, it can no longer spread out over a relatively large area, but is confined within that specific compartment, and has to be pumped away sooner. Furthermore, a fragmented water system is more expensive to maintain as each compartment needs to have sufficient surface water, water storage and pumping capacity (Schuten, Interview, 2017).

The biggest reason to question the resilience in the approach of ground water regulation is the fact that it enhances the cause of the problem that it is trying to solve. By extracting water from the soil and pumping it away it causes an increase in soil settlement, which results in more land subsidence. And if this soil upon which agriculture takes place is peat, then the extraction of ground water does not only cause an increase in settlement, but also in oxidation (Nieuwenhuis, Interview, 2017).

Also the resilience of the method in flushing surface water with fresh water adjacent to fields with salinization problems can be questioned, as this is an approach that is only working partially and temporarily. District water boards are able to refresh main water veins in the system, but smaller and distant brooks are very hard to reach (Bijl, Interview, 2017). Furthermore, it is a method that needs to be repeated once the salt levels are too high again. It needs a never-ending influx of money and energy and is challenging the efficiency (Van Kalsbeek, Interview, 2017). Flushing salinized surface water with fresh water is a method that is therefore only soothing the effects and is not tackling the cause of the problem.

Chapter 2.4 described two perceived paradigm shifts in Dutch water management to increase resilience. Restemeyer et al. (2015) described that we are moving from 'fighting the water' to 'living together with water' and Ritzema & Stuyt (2008) described the paradigm shift that the Delta Committee agreed upon in 2008, as they stated that the focus should move from; pumping and drainage, to the three-step approach of *'retention - storage - removal'* (Hoekstra & Nijburg, 2009). However, we can conclude that the present approach of increased water regulation with more fragmentation of water systems and prioritizing pumping capacity over storage and retention is still considering water as an enemy that needs to be fought. Moreover, the perpetual process of flushing salinized surface water with fresh water could be slowed down or even stopped when more emphasis would be placed on the retention and storage of fresh (rain) water. This topic will be further elaborated in the next section of this thesis.

Because of their nature and because they appear not to be moving along with the current paradigm shifts in Dutch water management, we may conclude that our current methods in dealing with both the quantitative and qualitative water-related issues that arise from land subsidence, lack in resilience.

4.4 | BUILDING ON RESILIENCE

Although increasing pumping capacity and fragmenting the water system has been a widely applied approach to relieve agriculture in the north of the Netherlands from the water-related issues arising from land subsidence, we can currently see a paradigm shift within the district water boards as they noticed that a fragmented water system is not a robust (Restemeyer et al., 2015) water system. The main reasoning behind this paradigm shift is the precipitation argument as was described in the previous section, and for this reason a further fragmentation of water systems is considered as undesirable by most district water boards. The province of *Friesland* - that developed a very fragmented water system over time because of this approach - is now even trying to reconnect separated compartments again, to make them bigger. Also costs considerations play a considerable role in this new paradigm (Wouda, Interview, 2017). The scale size of water level compartments is of great influence on how resilient the water system is. Even though farmers often prefer this fragmentation to create the most favourable conditions for their agricultural fields, we should refrain from further fragmentation. The bigger the water compartments are, the better (Bijl, Interview, 2017). This seems to be an important step towards a more resilient agricultural sector regarding these water-related issues.

A major step in increasing resilience is to raise awareness, both public as well as private awareness among the stakeholders (Restemeyer et al., 2015). One has to be aware of a problem, before the problem can be solved. Anticipating on a changing future, gives us more insight in the problems that lie ahead (Van Kalsbeek, Interview, 2017). There are various ways of increasing this awareness. The district water board *Zuiderzeeland* has for example started their '*Actieplan Bodem en Water'* (2014) in which they discuss the issues with farmers that are or will be affected by the water-related issues of land subsidence. With this, they also want to raise awareness amongst farmers about their own influence on the problems they perceive and stimulate intrinsic changes in their agricultural methodology. The usage of heavy machinery on fields can for example have a stimulating effect on the compaction and consolidation of the land and therefore enhances land subsidence. Furthermore, soils with a high amount of humus are able to store more water than soils with a low amount of humus (Leijten, Interview, 2017). An area-specific prohibition on ploughing can reduce the oxidation of peat (Wouda, Interview, 2017). These are three examples of intrinsic measures that a farmer could take into account to make his own company and methodology more resilient. Creating more awareness is therefore a crucial step in this process. Farmers should think about the long term processes (Nieuwenhuis, Interview, 2017). This might be a difficult task as a proportion of farmers tend to think very short term and are not aware of the problems that lie ahead, or are not open for change. It is a group that is very hard to reach (Wouda, Interview, 2017). Therefore, increasing awareness, stimulating this long-term thinking processes and anticipation is key in obtaining more resilience in agriculture.

An important aspect in increasing this awareness is that all the stakeholders are involved. Both Restemeyer et al. (2015), as well as Gersonius et al. (2015) stress the importance of an integrated, holistic approach on resilience. This is no different regarding this topic as the water-related issues arising from land subsidence are encompassing much more than just the agricultural sector. However, we can currently see that there is much improvement possible in the cooperation between farmer- and nature organisations, district water boards, local and regional governments, and third parties, such as the NAM regarding these problems (Van Kalsbeek, Interview, 2017). These are problems that cannot all just be placed on the expence of the farmer (Bijl, Interview, 2017). To increase resilience, a move towards a more holistic approach (also to enhance further awareness raising, anticipation and long-term thinking) should be made.

The answer to the more qualitative water-related issue of land subsidence: the increased salinization, may be found in the retention of fresh water (Tolk & Velstra, 2016). Currently, we saw that most farmers have the tendency to drain affluent water away to obtain the most favourable conditions for their fields. However, we should be more careful with the fresh water from precipitation. With special draining techniques farmers can try to retain fresh rainwater as long as possible as this reduces salinization problems (Bijl, Interview, 2017). A large pilot project, called '*Spaarwater'* (2017), took place, in which a water buffer and small tubes are laid out underneath agricultural fields. In times of precipitation these tubes function as drainage for affluent water, and store water in this buffer. In times of drought the stored water in this buffer can be used to irrigate the fields via those tubes (*figure 6*). This retention of water cannot only reduce the salinization, but the district water board Zuiderzeeland is using the same technique to slow down the oxidation of peat as well (Nieuwenhuis, Interview, 2017). Although such innovative techniques are quite costly, it delays or resolves both the quantitative- and qualitative water-related issues arising from land subsidence. This approach fits very well into the paradigm shift of the Delta Committee (2008): "Instead of increasing pumping and drainage capacities further and further, the focus has been shifted to control drainage in a three-step approach of decreasing priority: (1) retention of excess rainfall in the soil, (2) storage of remaining excess water in the field or the (field) drainage system and (3) controlled removal" (Ritzema & Stuyt, 2015, p.82). Therefore it is undoubtedly a way to implement more resilience into the agricultural sector and food production.

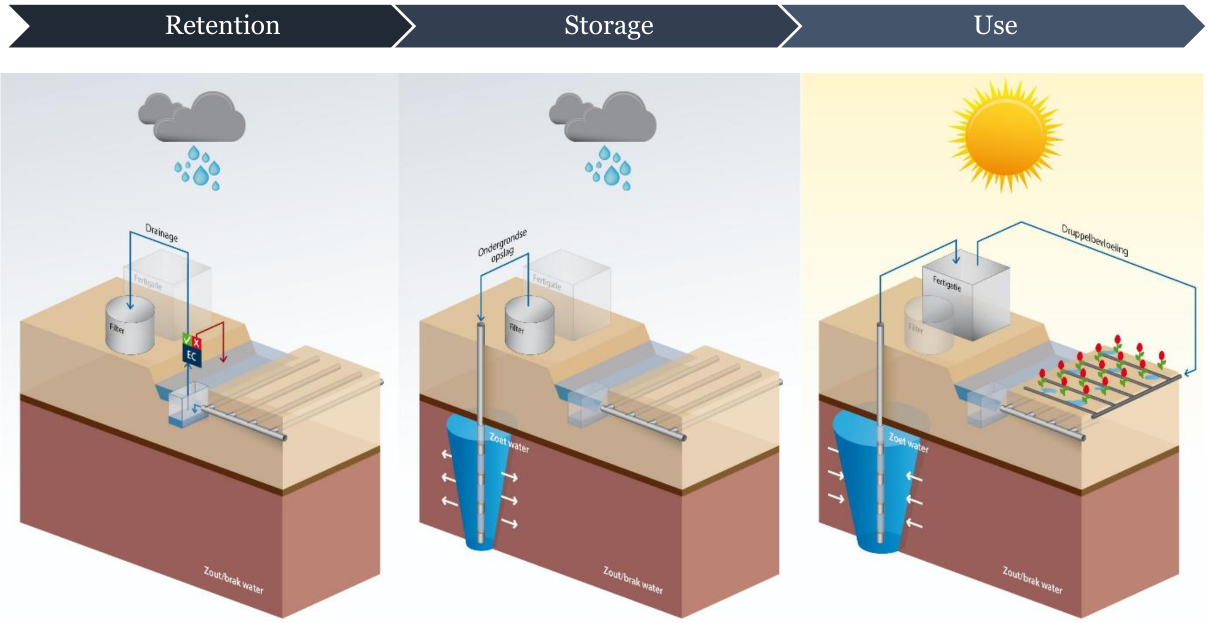

Figure 6: The technical operation of project 'Spaarwater' (Stichting Waterbuffer, 2017)

Another measure to create more resilience and in line with this paradigm shift, is the development of more water storage opportunities as this reduces the stress of peak discharges in periods with intense precipitation (Ritzema & Stuyt, 2015). With water storage you are giving space to the water in times of great rainfall excess (Schuten, Interview, 2017). However, this is a classic example of the never ending conflict between our environment and space. The creation of water storage with just that single land-use is undesirable as it takes in a lot of space. (Bijl, Interview, 2017). Therefore, it seems that we have to seek for resilient solutions in multi-combined land uses, such as the creation of overflow areas with a combined function of, for example, nature or agriculture under normal conditions, and storage of affluent water in times of intense water excess (Schuten, Interview, 2017). However, the layout of the water system is of influence in the fact of such an overflow area can be created, as you need to have multiple compartments of which you can regulate the water level independently (Leijten, Interview, 2017).

In the long term, there are some examples of measures to increase resilience that are more profound and far-reaching. Farmers can for example think about investing in crops that can cope better under wetter conditions, for examples rice or bulrushes. However, currently these crops are lacking in earning capacity (Leijten, Interview, 2017) and a market still needs to develop (Wouda, Interview, 2017). But the search for resilient crops goes beyond this point. In fact they should also be more resistant against salty conditions, and more resistant against the effects of climate change (Schuten, Interview, 2017). Another resilience-increasing, long term, process could be the re-division and re-allotment of agricultural land. A farmer on relatively wet grounds that cultivates labour intensive crops such as flower bulbs could in this case swap locations with a livestock farmer on relatively dry grounds (Leijten, Interview, 2017). This transition is predicted to take place more often in the upcoming ten years (Nieuwenhuis, Interview, 2017).

A last remark that needs to be made in the movement towards more resilient agriculture and food production is acceptance. We need to accept that our world is changing and that both financially as well as technically it is not possible to create the most favourable conditions for agriculture anymore (Wouda, Interview, 2017). The *theoretical framework* established that 'resilience in food production' basically is the responding to food insecurity, which is largely dependent on the capacity of a community to 'transform' (Cutter et al., 2008). The three step approach of 'acceptance - awareness - anticipation', of which the importance was stressed by Restemeyer et al. (2017), is therefore closely connected to, and seems to be the way to come to this 'capacity to transform'.

5. Conclusion

5.1 | MAIN FINDINGS

This thesis strived to complement, and fill gaps in our theoretical framework about the water-related issues that arise from land subsidence in the north of the Netherlands, and how the agricultural sector can increase its resilience against these issues. Land subsidence is affecting the sector almost everywhere in the study area, although the problem differs from region to region because of the various causes and influential factors. We have seen that land subsidence can result into two water-related issues. The direct and quantitative issue that agricultural lands are becoming wetter as the distance between the ground level and the ground water table is reducing, and the indirect and qualitative issue of increased salinization along the coastal regions (Bijl, Interview, 2017). This, additional to the implications that climate change brings along, results in an alarming situation for much of the arable land and will increase the amount of shock, stress, disturbance and disaster (Smith & Lawrence, 2014) events.

The measures that we are currently relying on the most in solving these issues are increasing drainage and pumping capacity and the fragmentation of our water system (to solve the quantitative water-related issue of land subsidence), and the flushing of surface water around salinized fields with fresh water (to solve the qualitative water-related issue of land subsidence). However, by interpreting the obtained data, both methods can - to a large extend - be seen as examples of reactive measures of which the resilience (Gersonius et al., 2016) can be debated. Especially since this approach of ground water regulation enhances the cause of the problem that it is trying to solve. The main aim of this thesis was therefore to search for approaches, methods or measures to increase the resilience of the agricultural sector in the north of the Netherlands regarding these issues. This was done along the main research question: *How can agriculture and food production in the north of the Netherlands become more resilient to the water-related issues that arise from land subsidence?*

From the results it appeared that the first steps to come to more resilience in agriculture are acceptance, awareness and anticipation. We need to accept that the world is changing and that both financially as well as technically it is not possible anymore to create the most favourable conditions for agriculture (Wouda, Interview, 2017). This will affect large regions in the north of the Netherlands and therefore there needs to be an increasing awareness of the problem. Farmers must be aware of the intrinsic measures to alleviate these water-related issues, such as avoiding work with heavy machinery on wet soils, stimulate the amount of humus in their soil (Leijten, Interview, 2017), or area-based ploughing prohibitions (Wouda, Interview, 2017). However, it is not only the farmers that need to have an increase in awareness of the problem, as the water-related issues of land subsidence are encompassing much more stakeholders. These issues should be addressed holistically (Restemeyer et al., 2015), just as the anticipation to those problems. Resilient ways to anticipate on these water-related issues move along with the paradigm shifts as described by Ritzema & Stuyt (2015) and Restemeyer et al. (2015). Instead of fighting the water we should live more together with it, and our focus should move from increasing pumping and drainage capacities further and further towards the three-step approach of *'retention - storage - removal'* (Hoekstra & Nijburg, 2009). The project '*Spaarwater*' (2017) is a very good example of how this approach of retaining and storing water longer can alleviate both the quantitative water-related issue of land subsidence (as it delays some types of land subsidence) and the qualitative water-related issue of land subsidence: salinization. However, in this discussion about retention and storage, it is because of the ongoing conflict between the environment and space, it seems that we have to seek for resilient solutions in multi-combined land uses (Schuten, Interview, 2017). Further examples to increase resilience in the agricultural sector are the re-division and re-allotment of agricultural land (Leijten, Interview, 2017), or crop transitions to more climate change-resistant and salt-resistant crops (Schuten, Interview, 2017).

5.2 | POLICY ADVISE

Interpreting the knowledge gained during this thesis leads to the following policy advise:

1. **Change current methods**: prevent further fragmentation of water systems and focus on the retention and storage of fresh water.
2. **Intrinsic changes in agriculture methodology are necessary**: such as area-specific prohibitions on ploughing, stimulate the amount of humus in agricultural fields, and prevent the use of heavy machinery - especially on wet soils.
3. **Think about long term resilience-increasing changes**: such as the transition to more salt-resistant and climate change-resistant crops, and the re-division and re-allotment of agricultural land.

5.3 | REFLECTION

During the collection of the data the full size of the topic got through. This thesis tried to look at how the agricultural sector can be more resilient to the water-related issues that arise from land subsidence, however there are a lot of influential variables that determine the approach, method or measures that could make this aim happen, such as the type of land subsidence (natural or anthropogenic), the cause of land subsidence (oxidation, settlement, maturation, the natural subsidence due to the isostatic balance, and mining for natural resources), the composition of the ground, the land-uses that should be served at the surface, the influence of climate change, the layout of all the different water systems within the research area, and different financiers of the problem. It was simply too broad to profoundly cover it all. Some topics only have been mentioned very shortly as a word limit had to be adhered to. This broadness also led to the fact that in the end some parts of the *Theoretical framework* were not relevant anymore in connection to the obtained information from the interviews. As they could not be mentioned anymore, a substantial part of this *Theoretical framework* was removed from this thesis. Maybe the best way to reduce the scale of this research was to reduce the study area from '*the north of the Netherlands'* to a smaller-scale region.

A positive point of the data collection was that even though people with different backgrounds and positions were interviewed, roughly the same questions were asked. The interview guides were made with great care, and it led to the fact that after six interviews a lot of useful, but also comparable information, was obtained. Therefore the coding and encrypting process was rather easy. More difficult however was to link those code words - and so the citations of the interviewees - to one of the four parts of the thesis (*Land subsidence and its water-related issues, Methods in dealing with the effects of land subsidence for agriculture, Assessing resilience,* and *Building on resilience*). This was mainly due to the fact that interviewees would merge those parts automatically within their answers. For example, when they mentioned a water-related issue of land subsidence for agriculture, they directly stated methods against these issues and included the advantages and disadvantages of this particular method. A lot of answers therefore had to be split up over different code words, and also different parts of this thesis.

Other than these issues, the entire process which eventually led to this thesis went rather smooth though with hard work and commitment.

5.4 | OUTLOOK

The broadness of this thesis lead to a lot of recommendations for further research, as much of the topics mentioned during this thesis can be looked upon in more detail. This thesis can therefore function as a starting point to do this as it gives an overview upon the water-related issues of land subsidence and the possible methods to increase resilience regarding this topic. Examples of areas that could be investigated further are a large-scale extension or application of the project *'Spaarwater'* (2017), further implications of the holistic approach regarding this topic, or an elaboration on the transition to climate change-resistant and salt-resistant crops.

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