Plausibility of pathways for landscape development in peat meadows:

An exploration of the Amstelscheg case study

Stedenbouw & Landscapes (2019)

Master Thesis Water Science and Management

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Preface

After about six months of work, I hereby present the final report of my MSc. graduation research. When I started to explore the possibilities in the graduation topics and possible ways to conduct this final product of my Master's in Water Science and Management, the first decision was to look for a position where I would not only get my very last grade for university, but where I could also get acquainted with water issues in practice. Therefore, I am very grateful to Deltares and De Natuurverdubbelaars for giving me the opportunity to gain experience through a graduation internship.

First of all, my appreciation goes to Sien Kok of Deltares, Daan Groot of De Natuurverdubbelaars, Carel Dieperink and my second reader, Martin Wassen, of Utrecht University, who assisted me in this intensive project, also in times of COVID-19, and provided me with their useful and refreshing insights and criticism. Furthermore, I would like to thank my colleagues and fellow interns of Deltares and De Natuurverdubbelaars for the support and information they have given me on this versatile subject. Finally, I would like to thank Stefan, and my friends and family, especially my father and my brothers Bas and Jeroen, for reading my thesis and for the necessary distraction during the weekends, especially in these odd times with COVID-19. This is probably the final piece of my student life, in which I learned a lot and really started to love the wonderful world of water. I look back on an exciting and valuable experience and I am looking forward to a career in which this journey will continue.

Lotte van Helden,
Amsterdam, 29-07-2020

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Summary

Large parts of the Western Netherlands, including the so-called Green Heart (Groene Hart), consist of peat meadows. Soil subsidence occurs in these areas, mainly as a result of oxidation of peat above the artificially lowered groundwater level. Soil subsidence causes increased vulnerability to flooding, economic losses due to damage to homes and infrastructure and increased emissions of greenhouse gases. Therefore, governments are exploring sustainable approaches to reduce soil subsidence in peat meadows.

Currently, land use determines which water management is needed. In 2019, a design study was carried out for the Green Heart examining what would happen if water management were to be set up to stop or reduce soil subsidence and CO_2 emissions, while the land use would adapt. In this same study, a case study was carried out for the Amstelscheg, for which two future scenarios were developed: Production landscape & Nature landscape. In the first scenario, agriculture remains the primary function in the area, but with more nature-inclusive agriculture, paludiculture and submerged drains, to reduce soil subsidence. The second scenario assumes maximization of biodiversity and active peat recovery, by transforming current agricultural use into nature.

There are numerous projects on tackling soil subsidence in the Green Heart, but implementations and upscaling are difficult to initiate. The route to implementation is also absent in the design study containing the two future scenarios. This study therefore focuses on what strategy can be followed to implement these future land use scenarios. One way of providing insight into what possible measures can be taken to prevent soil subsidence is by creating an adaptation pathway. This can help policymakers to decide which measures need to be taken and when. In scientific literature this adaptive approach has not been used before in the context of soil subsidence due to peat oxidation. This knowledge gap is addressed in this study.

The aim of this study is to identify the plausibility of pathways for landscape development in the Green Heart. Plausibility depends on the suitability and feasibility of a pathway. First of all, it was studied what pathways are, what pathways are used for and what the limitations of pathways are. Subsequently, a stakeholder analysis was carried out to determine which actors are important in the Amstelscheg and what their formal tasks, competences, interests, goals and problem perceptions are. The selected stakeholders were interviewed about their future visions for peatlands, the scenarios and what is needed to realize these future visions. The results of the interviews were compared in order to arrive at the most plausible pathway. In addition, a roadmap was created that provides insight into how the implementation of the pathway can be achieved.

The results show that the production landscape is preferred by most stakeholders. A combination of agriculture in a much more extensive form, places where meadow birds can breed, and possibly places where paludiculture is practiced. In addition, this study shows that within the water system there should be more focus on controlling drought and not only on controlling floods, as is still often the case in the Netherlands. Moreover, the results showed that a step-by-step approach is preferable compared to a transformation overnight, and the adaptation pathway approach can be a valuable method in this respect. Although defining tipping points proved to be a challenge for adaptation pathways in the context of soil subsidence, the method is useful for identifying different measures, prioritizing these measures and planning them over time.

1. Introduction

Many deltas and coastal plains over the world are sinking due to, among other things, groundwater extraction and drainage of land (Galloway & Burbey, 2011). These deltas are often densely populated, and together with climate change, this leads to an increasing pressure on water management (Haasnoot, Middelkoop, et al., 2012). In most of these inhabited coastal plains, sedimentary and hydrological processes are managed to promote e.g. flood safety and arability (Erkens et al., 2016).

1.1. Soil subsidence in Dutch peat meadow areas

One of the reasons why soil subsidence occurs in the Netherlands is that most peatland areas are drained so they can be cultivated, and then aeration causes peat to first shrink and then oxidize (Erkens et al., 2016). Oxidation occurs in the aerobic soil layer above the groundwater level. If groundwater levels are lowered, which is required to maintain a suitable freeboard (the distance between surface water level and field elevation) for agriculture, a larger volume of peat becomes subject to oxidation and soil subsidence is accelerated (Querner et al., 2012). Furthermore, oxidation also leads to emissions of carbon dioxide (CO_2) and this is becoming an important issue in view of the Climate Agreement (Erkens et al., 2016). In addition, peat consolidates when loaded, resulting in even more volume reduction and soil subsidence (Erkens et al., 2016). By permanently lowering the water level, the peat layer will eventually disappear completely.

In the western part of the Netherlands, the Green Heart (Groene Hart), peat layers that are more than 2.5 meters thick occur (Makaske et al., 2004). In theory, the surface in these areas could subside by 2.5 meters. The current average yearly rate of soil subsidence is 1 centimeter in the Green Heart; this indicates a 30 centimeter drop by the year 2050 (*Kwaliteitsatlas Groene Hart*, n.d.). Figure 1 shows that there are also areas that are projected to subside over 60 centimeters by the year 2050 under current subsidence rates, and if no restrictive measures are taken. Climate change may significantly increase this soil subsidence rate. An increase of 2°C in 2050, combined with a change in air circulation will increase the soil subsidence rate, by almost 70% (Hendriks et al., 2007; Querner et al., 2012). For this map, a climate scenario has been used which indicates a 2°C increase in 2050 and with the lowest groundwater levels of the KNMI scenarios. Due to climate change, groundwater levels in peat areas are decreasing and the rate of peat oxidation is increasing, both of which lead to an increase in soil subsidence (Deltares et al., 2020).

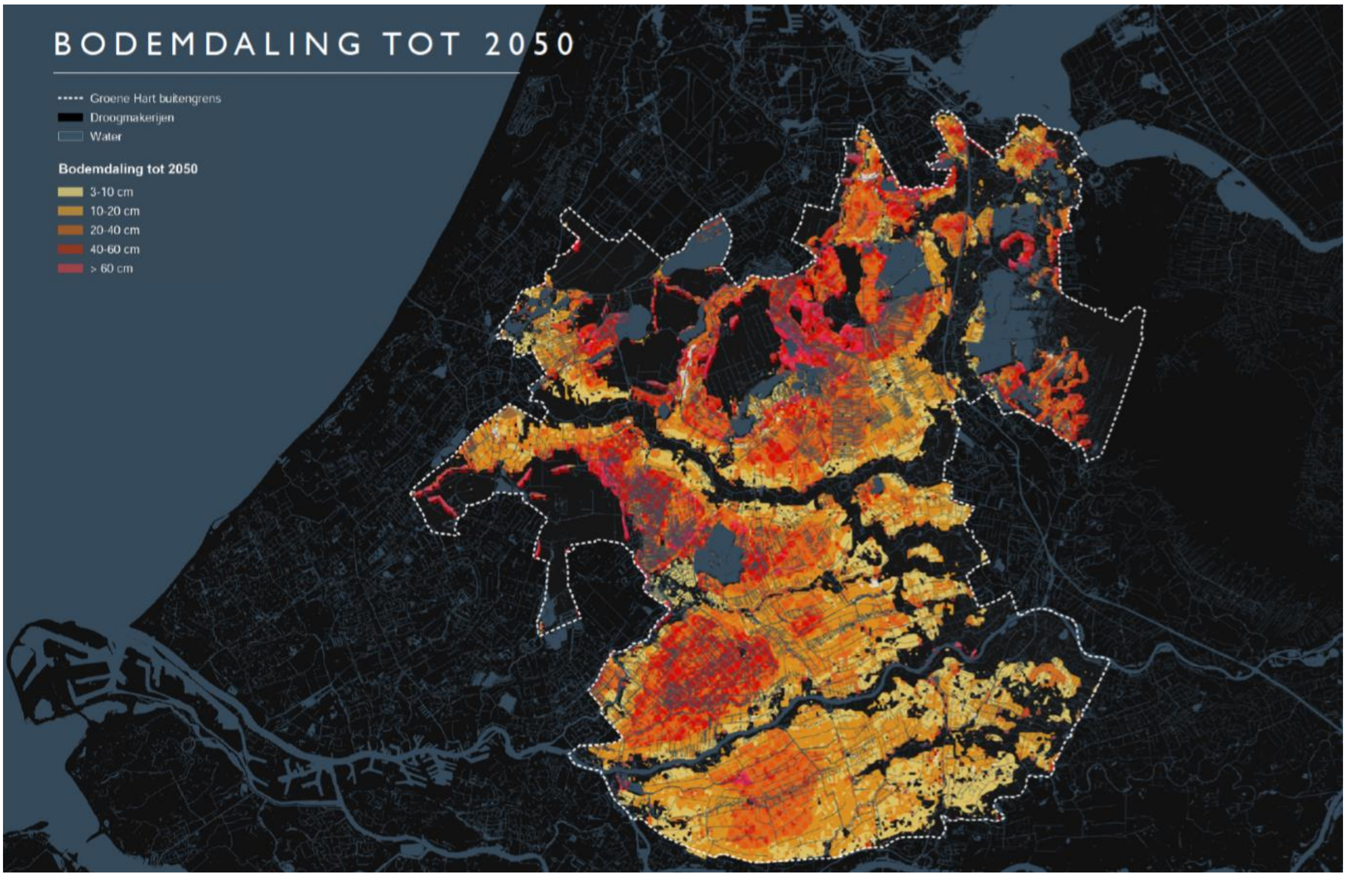

Figure 1: Soil subsidence in the Green Heart region until 2050 (Plambeck & Wijnakker, 2019)

Negative impacts of soil subsidence

Soil subsidence increases vulnerabilities to floods and leads to economic losses by affecting roads, hydraulic infrastructure, river embankments, sewage systems, buildings and foundations (Erkens et al., 2015). In peat meadow areas, peat oxidation leads to emissions of CO_2 and other greenhouse gasses (Erkens et al., 2016). The CO_2 emissions from peat oxidation is 4.2 Mton per year, in which the Green Heart accounts for 1.4 Mton (Plambeck & Wijnakker, 2019). The total CO_2 emissions from peat oxidation is about 2.5% of the total anthropogenic CO_2 emissions of the Netherlands (den Akker et al., 2010). CO_2 emissions from peat oxidation also account for more than 23% of the total annual emissions of the Dutch agricultural sector, while peat meadows account for less than 10% of the area of agricultural soils (van de Riet et al., 2014). In view of the Climate Agreement, CO_2 emissions must be drastically reduced, including in the Green Heart. The Climate Agreement sets an emission reduction for peat meadows of 1.0 Mton in 2030. Eventually, emissions must be reduced by 90% or more in 2050 (*Klimaatakkoord*, 2019).

Another important driving force for addressing soil subsidence, are costs. The Netherlands Environmental Assessment Agency (PBL) calculated that soil subsidence poses considerable costs to society. In 2050, damage to homes and infrastructure in the peatlands throughout the Netherlands can amount to 22 billion euros (den Born et al., 2016). Moreover, soil subsidence is not the only challenge the Green Heart region faces in transition to a sustainable future; a large construction demand, sustainable transition of agriculture (new nitrate regulation; biodiversity), population growth, energy transition and mobility transition also pose challenges (van Egmond et al., 2018). For the reasons mentioned above, the government has set aside 10 million euros for the 'Regiodeal Bodemdaling' in the Green Heart region. The national government and the region will work together on projects related to knowledge development, future-proof building, and innovative entrepreneurship.

1.2. Pathways for dealing with soil subsidence

In order to cope with soil subsidence in peat areas, different strategies may be practiced. Generally, there are two policy strategies for subsiding areas: mitigation and adaptation. Mitigation measures focus on reducing or limiting the soil subsidence process itself and include raising water levels to reduce oxidation of organic matter. There are several methods to achieve raised water levels: submerged drains and inundation of peat meadow plots (den Akker et al., 2010; Kwakernaak et al., 2010; Smolders et al., 2019). Adaptation focuses on reducing the negative impacts resulting from soil subsidence, for example by using cattle breeds that are more productive under wet circumstances and implementation of soil subsidence-adaptive urban development and spatial planning (Abidin et al., 2015; Hotse Smit, 2019). A more extreme strategy would be to give up traditional dairy farming, and switch to paludiculture or convert the agricultural land to nature (Verhoeven et al., 2010; Wichtmann & Joosten, 2007). Adaptation and mitigation measures can be applied in the pathway approach. This is a method used to identify different measures, prioritize them and plan them over time (Fazey et al., 2016). Different mitigation and adaptation strategies represent different pathways.

1.3. Previous studies in the Green Heart on soil subsidence

Recently, two studies have addressed what happens when water management is set up to stop or reduce soil subsidence and CO_2 emissions, whereby land use adapts (Stedenbouw & Landscapes, 2019; Plambeck & Wijnakker, 2019). The type of land use currently determines the degree of drainage. The study offers potential business models and water measures. During that same study, three case studies were simultaneously conducted in three different areas in the Green Heart. One of these case studies was conducted in the Amstelscheg (Stedenbouw & Landscapes, 2019). Two scenarios were made for the Amstelscheg: 1) Production landscape, 2) Nature landscape. In the first scenario, agriculture remains the primary function in the area, but with incorporating, for example, nature-inclusive agriculture, switching to different (wet) crops or submerged drains, to reduce soil subsidence. The second scenario assumes the maximization of biodiversity and active peat recovery, through the transformation of current land use from agriculture to nature. Priority in this scenario is to restore raised peat bog since this peat component has almost completely disappeared from the Green Heart due to extraction and reclamation. This peat can capture CO_2 and retain a lot of water. Experiments with peat repair are already being carried out on a small scale, for example in Ilperveld (Stedenbouw & Landscapes, 2019).

Furthermore, Waternet and Regional Water Authority (RWA) Amstel, Gooi and Vecht (AGV) have carried out a social cost-benefit analysis (SCBA) regarding peat soils in the AGV area (Pelsma et al., 2020). The social costs and benefits have been calculated using four scenarios, which includes the costs of water management, dikes, infrastructure, foundations and the net added value of agricultural activity. Besides, the study looked at soil subsidence for the four scenarios, and emissions of greenhouse gases. They conclude that the current policy leads to the largest soil subsidence and greenhouse gas emissions. Active rewetting leads to the smallest soil subsidence and the lowest emissions.

Another study, by Ellen & Hommes (2017), used pathways as an instrument for the sustainable management of soil subsidence in the Green Heart. Policy and decision-making on soil subsidence are suffering from 'non-decision making'. The pathway approach proved to be a valuable tool to stimulate discussion on what would be needed in the area of governance.

1.4. Knowledge gap

As mentioned in section 1.3., several parties are working on tackling soil subsidence in the Green Heart. There are numerous projects, programs, and pilots, but implementation and upscaling are difficult to initiate (Regio Deal Bodemdaling Groene Hart, 2020). The route to implementation is also absent in the study by Stedenbouw & Landscapes (2019), which outlines future land use scenarios. This study therefore focuses on what strategy can be followed to implement these future land use scenarios. In order to investigate this, the approach of pathways is used. There are two types of pathways: adaptation and transition. Adaptation pathways have so far been used mainly in the context of water safety and transition pathways for energy transitions (Geels & Schot, 2007; Haasnoot et al., 2013). These methods have only been applied for soil subsidence due to oxidation of peat in the study by Ellen & Hommes (2017).

1.5. Research aim and relevance

The aim of this study is to identify the plausibility of pathways for landscape development in the Green Heart. Plausibility depends on suitability and feasibility (Soria-Lara & Banister, 2017). This study will result in practical recommendations to the different actors in peat areas, such as policymakers and farmers. In line with the aim of this study, the research has both scientific and societal relevance. From a scientific perspective, this study uses the pathways approach in a new context, with the exception of the report by Ellen & Hommes (2017), the approach has not yet been applied in the context of soil subsidence (section 1.4.). Therefore, this study provides insight into the usefulness of this approach in a context of soil subsidence and contributes to the existing literature on soil subsidence and pathways in general. In addition to scientific relevance, this study also has social relevance. Firstly, the study provides the most plausible pathway for the Green Heart as a recommendation for policymakers and other actors. Secondly, practical recommendations are provided on what strategy could be followed to implement the future land use scenarios as sketched in the study *Design Research Green Heart* (Stedenbouw & Landscapes, 2019).

1.6. Research questions and framework

The research aim that was formulated in the previous section translates into the following research question:

What could be plausible pathways for addressing soil subsidence in peatland areas in the Green Heart?

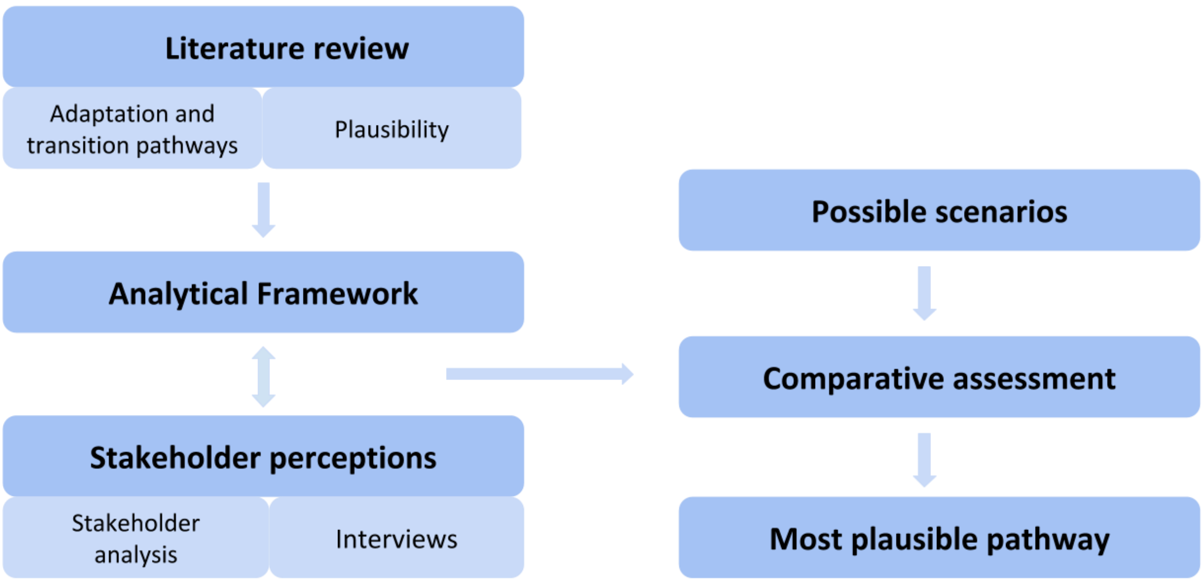

Figure 2: Research framework

The research framework depicted in figure 2, shows which steps had to be taken in this study in order to answer the main research question. The first part of the illustrated research framework is the *Literature review*. A literature research on pathways and indicators was carried out to assess the plausibility of pathways. The information collected there was used as a basis for the entire study. This led to the second part, the *Analytical Framework*: a step-by-step plan containing the key concepts for empirical research. Subsequently, possible scenarios for the Amstelscheg have been identified. The scenarios of Stedenbouw & Landscapes (2019) were used for this purpose. The scenarios were used in the *Stakeholder perceptions* section, in which actors were interviewed about their vision on the future of peatlands and what is needed for the realization of those future visions. Input from the stakeholders led to the next part, *Comparative assessment*, in which the most important results of the interviews and the analytical framework emerge. Then, in the section *Most plausible pathway*, the most plausible route is presented, and the most important lessons learned to promote the implementation of the pathways are extracted.

This results in the following sub-questions:

1. What key conditions account for the plausibility of a pathway?
2. What are possible scenarios for the Green Heart?
3. What perceptions do stakeholders have on the suitability of the scenarios?
4. What perceptions do stakeholders have on the feasibility of the scenarios?
5. What are the differences between the perceptions of the stakeholders?
6. To what extent are the key conditions present in the Green Heart?

1.7. Methods

The first sub-question was examined on the basis of a literature study on pathways and indicators to assess the plausibility of pathways. As a search engine, Scopus has been used with the following search terms: ‘pathways’, ‘adaptation pathways’ and ‘water management’, ‘transition pathways’ and ‘water management’, ‘pathways’ and ‘soil subsidence’, ‘indicators to assess pathways’ and ‘plausibility of pathways’.

For the second sub-question, the scenarios of Stedenbouw & Landscapes (2019) have been used. These are scenarios made for the Amstelscheg, an area south of Amsterdam. This area has been used in this study as a case study for the Green Heart. A case study has been chosen because it offers the opportunity to study the situation in depth. Moreover, it is possible to complete a case study in a relatively short period of time. More time would be needed to thoroughly study the entire Green Heart. In addition, for this second sub-question a stakeholder analysis was performed to identify the key stakeholders. Stakeholders are actors who contribute to a policy problem, are needed for problem solving, or are influenced by problem solving (Runhaar et al., 2006). According to literature, the following steps are usually distinguished in a stakeholder analysis (Grimble, 1998; Runhaar et al., 2006):

- Definition of the policy problem
- Identification of actors involved in the subject
- Identification of formal tasks, competences, interests, goals and problem perceptions of the actors involved

The steps above were conducted based on literature research. Besides, knowledge on the actors in the area was obtained from zoning plans, spatial structure visions and environmental visions of local, provincial and national governments. The method provided the necessary background information to better understand the dynamics in the policy process (Runhaar et al., 2006). The stakeholder analysis led to a network of stakeholders.

Subsequently, for the third and fourth sub-question, interviews were held with the key stakeholders about the scenarios for the Amstelscheg. The method of interviews was chosen because it allows to explore the views, experiences, beliefs and motivations of individuals about the future of peatland area in the Amstelscheg. Since this is a relatively sensitive topic for farmers, this method seemed the most appropriate (den Born et al., 2016). There are three types of interviews: structured, semi-structured and unstructured. For this study, semi-structured interviews were used because they provide a certain structure, but also allow the interviewer to diverge to pursue a response in more detail (Gill et al., 2008). This approach is more flexible compared to structured interviews, and easier to manage due to predetermined interview questions compared to unstructured interviews (Gill et al., 2008). The topics used in the interviews with stakeholders were based on the analytical framework. The interview questions can be found in appendix F.

For the fifth sub-question, the interviews were transcribed and analyzed. The program NVivo was used as Computer Assisted Qualitative Data Analysis Software (CAQDAS) (Welsh, 2002). The first step was open coding, which included very carefully reading all the data collected so far and dividing it into fragments. The relevant fragments were labeled and compared. Codes are a summary notation for a piece of text, in which the meaning of the fragment is expressed. Pieces of text were highlighted and given a summary name under which they were stored. The result of open coding was a list of codes. The next step was axial coding. Here it was determined whether the codes developed so far sufficiently cover the collected data. In addition, all fragments were run through to see whether it was correctly coded or whether it belonged to another code (Boeije, 2005).

Lastly, for the sixth sub-question, a multi-criteria analysis was carried out to assess the plausibility of the scenarios. Suitability and feasibility jointly determine the plausibility of a pathway. Four indicators to explain the feasibility of a measure were used: power, motivation/cooperation, resources and dependence. The key indicators were used in a performance matrix, a standard feature of a MCDA. It sets out how each of the measures from the scenarios performs on each of the key conditions that form part of the analysis (Dodgson et al., 2009). Weighting of the key conditions was not used in this study, they have been considered equivalent. The size and complexity of a measure or policy instrument to be implemented was scored on a scale from 1 to 5 (1 = easy to implement, 5 = difficult to implement). The multi-criteria framework for scoring the plausibility of measures is shown in table 1. The results were used to create a roadmap and an adaptation pathway. Calculations were made for the adaptation pathway to calculate the remaining drainage depth up to 2100, and the measures for farmers were linked to the remaining drainage depth. The method for this can be found in Appendix D.

Table 1: Multi-criteria framework for plausibility (Hommes, Ellen, & Seijger, 2018).

Indicator					
Is the change desirable for the stakeholders? **(suitability)**	1 (very desirable)	2	3	4	5 (not desirable)
Can the change be carried out by one organization or does it require multiple organizations? **(power)**	1 (one organization)	2	3	4	5 (more than 4 org.)
Are the organization(s) willing to implement the change (together)? **(motivation/cooperation)**	1 (willing)	2	3	4	5 (unwilling)
Do the necessary organizations have the resources to implement the change? **(money, knowledge, time)**	1 (money, knowledge, time)	2 (surmountable)	3 (inadequate)	4 (totally inadequate)	5 (none)
Does the intended change depend on other changes in political, social, and economic structures? **(dependence)**	1 (nil)	2	3	4	5 (much)

1.8. Outline of the report

Chapter 2 discusses the literature on pathways and their plausibility. This results in an analytical framework. Chapter 3 describes the case study the Amstelscheg and identifies the scenarios used in this study. Chapter 4 describes the results, the perceptions of stakeholders on the plausibility of the scenarios. Subsequently, the results are discussed in chapter 5. Finally, chapter 6 provides the conclusion and recommendations for the stakeholders and researchers.

2. Literature review on the plausibility of pathways

2.1. Introduction

This chapter explains what pathways are, how they are used, by whom and what the limitations of pathways are. Thereafter, adaptation and transition pathways are explained, examples are given and their use in literature is described. Furthermore, it is explained how the plausibility of pathways can be assessed using various indicators, a cost-benefit analysis and a multi-criteria decision analysis. Finally, the analytical framework is outlined.

2.2. Pathways: use and limitations

Pathways are used for planning, identification of different measures and how they can be realized (Fazey et al., 2016). Policymakers can, for example, make use of climate adaptation pathways. The changing climate and its consequences are uncertain in terms of rate and magnitude. It is important to know what the possibilities are to prevent damage, unsafe situations and costs in the future. Pathways can help identify the policy choices that exist and prioritize problems and solutions (Deltares, n.d.).

According to Haasnoot et al. (2012) adaptation pathways provide “an analytical approach for exploring and sequencing a set of possible actions based on alternative external developments over time.” The definition of Barnett et al. (2014) is “an adaptation pathway is a decision strategy that entails a vision for the entity exposed to climate risks, to be met through a sequence of manageable steps over time, each of which is triggered by changing environmental or social conditions”. Geels & Schot (2007) argue, “transitions can be induced through rational action, as well as through changing interpretations or power struggles.”

One limitation is that actions that seem evident now may turn out to be maladaptive as the actual risk situation manifests, even in the pathways approach. However, by explicitly considering a range of possible futures and identifying long-term options, the risk of maladaptation is reduced (Bloemen et al., 2018). In addition, Wise et al. (2014) observe a focus on direct causes and incremental actions and a lack of more systemic or transformative actions. In theory, the pathways approach is ‘neutral’ to the choice of the type and sequence of measures. However, practice indicates that the preferred pathway often contains incremental measures in the short term, more stringent measures in the medium term and system-changing interventions in the long term (Bloemen et al., 2018). Another implication of the adaptation pathway approach is that defining tipping points is a challenge in contexts other than gradually changing developments, such as sea level rise. It is not always possible to determine the exact timing of tipping points (Bloemen et al., 2018).

2.3. Adaptation pathways

In general, there are two different types of pathways: adaptation and transition. Adaptation pathways are focused on dealing with deep uncertainties and were developed in the context of climate change (Haasnoot et al., 2013). The objective is to gain insight when strategies are no longer feasible and/or no longer meet current standards and/or policy agreements. An adaptation pathway provides a visual representation of the various actions and potential sequencing that could be implemented in the future (Kingsborough et al., 2016). Rather than deciding now about the one or two ‘best’ adaptation strategies, several measures are considered, making the approach more flexible. This approach is designed to ensure that whatever plan is adopted for the short to medium term, it is set in a framework that will not be unsuitable if social, environmental and economic conditions change differently from what is currently forecasted as “most likely” (Reeder & Ranger, 2011). For each adaptation option, the following is assessed: the key threshold at which that option would be required (for example, the extreme water level); the lead time needed to implement that option; and thus, the estimated decision point to trigger that implementation (Reeder & Ranger, 2011). By using adaptation pathways, stakeholders get the opportunity to consider a range of possible futures, identify adaptation options, and sequence them over time (Cradock-Henry et al., 2020). An example of an adaptation pathway can be seen in figure 3 below.

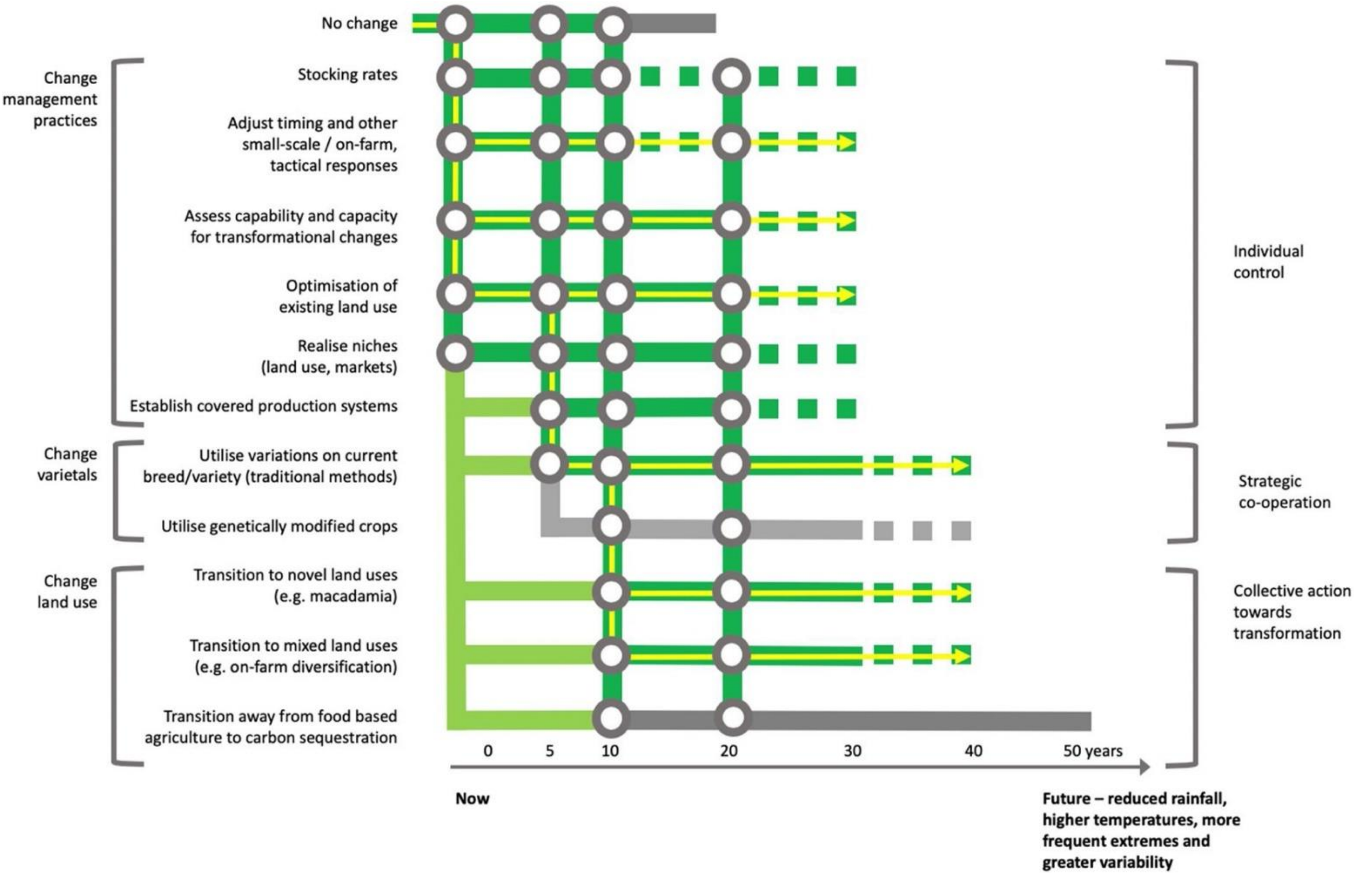

Figure 3: Example of an adaptation pathway (Cradock-Henry et al., 2020). It shows a regional adaptation pathway for agriculture in Hawke's Bay. Green lines indicate how long an adaptation option is suitable (dark green) or the time it takes to prepare (light green). Dashed lines indicate that the adaptation can contribute to a solution. Grey lines indicate options that currently cannot be applied (light grey) or are not preferred (dark grey). The yellow line represents the preferred routes identified by stakeholders in workshops. Circles indicate point in time at which decisions should be made or the adaptation option changed.

Adaptation pathways in literature

Adaptation pathways have been widely used in studies regarding water management, urban drainage infrastructure, flood risk and agriculture (Cradock-Henry et al., 2020; Haasnoot et al., 2013, 2015; Haasnoot, Kwakkel, et al., 2012; Haasnoot, Middelkoop, et al., 2012; Kapetas & Fenner, 2020; J H Kwakkel & Haasnoot, 2012; Jan H Kwakkel et al., 2015; Manocha & Babovic, 2017, 2018; R M Wise et al., 2016). There are various approaches to develop adaptation pathways: assumption-based planning (Dewar et al., 1993), real options (Hertzler, 2007; Jeuland & Whittington, 2014; Woodward et al., 2014), adaptive policy making (Hamarat et al., 2013; Walker et al., 2001), dynamic adaptive policy (Kwakkel et al., 2010), and dynamic adaptive policy pathways (Haasnoot et al., 2013). These approaches all use some type of signpost and trigger to identify when the policy needs to be changed.

The Dynamic Adaptive Policy Pathways (DAPP) approach was developed from the methods "Adaptive Policymaking" and "Adaptation Pathways" (Haasnoot et al., 2013). The DAPP approach includes the uncertainties about the future arising from social, political, technological, economic, and climate changes. This approach uses 'adaptation tipping points' to indicate at which point a certain action is no longer satisfactory to achieve the targets. A new action must then be implemented (Haasnoot et al., 2013). An example of the concept of adaptation tipping points is the greenhouse gas emission policy by setting a standard for greenhouse gas reduction. The reductions must be such that the global temperature increase does not exceed 2°C by the end of this century (Kwadijk et al., 2010). A more detailed description of the DAPP approach can be found in Appendix A.

Besides the use of pathways in scientific literature, pathways have also been used in grey literature. For example by Ellen & Hommes (2017), who used pathways as a tool to inform governance bodies about sustainable management of soil subsidence. They further developed their approach into a "subsidence canvas" (Ellen et al., 2018). The first step of the subsidence canvas involves clarifying and structuring the problem. The second step is to identify possible interventions with all the actors involved. Subsequently, in the next step, promising interventions are assessed in terms of their effectiveness, feasibility and support, and administrative agreements are developed. Characteristic of the design approach is that every phase in the process goes into collaboration with the actors involved. A more detailed description of the 'subsidence canvas' can be found in Appendix A.

The study by Soria-Lara & Banister (2017) assesses the plausibility of pathways on the basis of indicators suitability and feasibility. Suitability indicates the extent to which the actors regard the pathway as desirable. Feasibility is divided into two different types: political and financial feasibility. Another study, by Hommes, Ellen, & Seijger (2018), uses four indicators to assess the feasibility of a pathway: power, motivation/cooperation, resources and dependence.

2.4. Transition pathways

Transition pathways revolve around the objective to reach one specific goal that is considered desirable, such as a degree of sustainability (Geels & Schot, 2007). In other words, in the case of transition paths, the final goal is clearly determined, while in the case of adaptation paths, flexibility and the choice of measures are key. When the aim is to fundamentally change a system, transition pathways can be used to sketch how this system change can be achieved (Geels & Schot, 2007). There are various models of transitions that are used to help understand the mechanisms underlying transitions (Holtz, 2011). The multi-level and multi-pattern model have been increasingly used in recent years. The multi-level model is one of the basic models to study transition dynamics. This model distinguishes between three levels at which developments take place that initiate transition. The regime level, which is the current system with fixed rules, routines and structures. The niche level, where innovative developments take place that deviate from the existing system. And lastly the landscape level, this includes major social changes over the long term (Geels, 2002). The multi-level model is visually shown in figure 4 below. An example of a multi-level model can be found in Box 1.

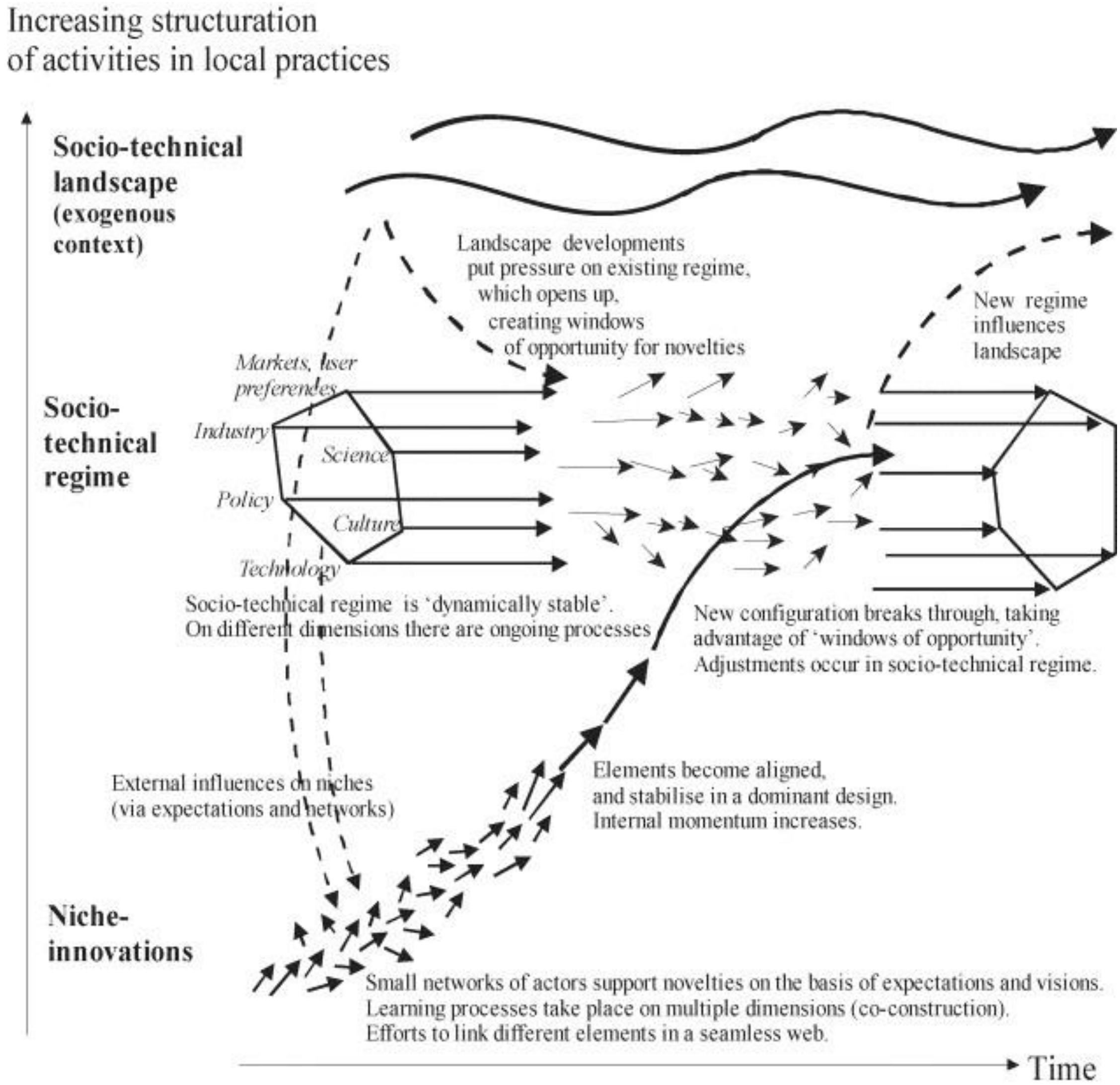

Figure 4: Multi-level perspective on transitions (Geels & Schot, 2007).

The multi-pattern model describes various patterns that make up a transition process (de Haan & Rotmans, 2011). The top-down pattern describes how a regime adapts to the external pressure of changes at the landscape level. Furthermore, the bottom-up pattern describes how a niche can break through from below and replace the existing regime. Lastly, the possibility of adaptation, which means that the existing regime changes its functioning by cooperating or merging with an emerging niche. The transition process is often made up of different combinations and repeats of these patterns (de Haan & Rotmans, 2011). By combining all these different combinations, a transition path can be visualised.

Box 1: Example of a multi-level approach
Van der Brugge et al. (2005) used the transition concepts of multi-level to reconstruct the historical development in Dutch water management. Their research shows that the water management regime has changed over the past thirty years from a technocratic scientific style to an integral and participatory style:

- 1975: Technocratic water management (top-down)
- 1985: Water System management (top-down)
- 1995: Integral water management (stakeholder participation)
- 2004: Adaptive water management (participatory Policy process)

An important starting point for this transition was in the 1970s, when the plan for the Eastern Scheldt storm surge barriers was adjusted. During the pre-development phase, there was a continuous process of integration between water management and nature development. The floods led to initiatives at the niche level, with the growing awareness among water managers that water problems were the result of an unsustainable water system at the regime level and the threat of anthropogenic climate change at the landscape level, shifting the transition to the take-off phase, in which thresholds are reached and the state of the system begins to shift.

In addition, transition pathways are part of transition management, a new governance approach for sustainable development (Loorbach, 2010). The transition management approach consists of a cyclical process model. The cycle consists of the following components: 1) structure the problem, develop a long-term sustainability vision and establish the network of actors with different backgrounds and perspectives; 2) develop future images, a transition agenda and derive the necessary transition paths; 3) mobilize actors and execute projects and transition experiments; 4) evaluate, monitor and learn lessons from the transition experiments and, based on these, make adjustments in the previous steps (Loorbach, 2010). Within the field of transition management, the backcasting approach is often used (Dreborg, 1996; Höjer & Mattsson, 2000; Quist & Vergragt, 2006; Soria-Lara & Banister, 2017). Backcasting is an approach in which transition pathways are used. The starting point is a certain desired future end point, and from that point measures are designed towards the present. This allows the plausibility of that future to be determined and makes it clear what policy measures are needed to reach that point (Robinson, 1990). A more detailed description of the backcasting approach can be found in Appendix A.

2.5. Plausibility: indicators, CBA and MCA

In order to be able to assess the plausibility of a pathway, the key conditions determining the plausibility of a pathway need to be identified. Plausibility depends on both suitability and feasibility. Here, the indicators for suitability and feasibility, and two methods for substantiation are presented: Cost-Benefit Analysis and Multi Criteria Decision Analysis.

As mentioned in sections 1.7 and 2.3, indicators suitability and feasibility are used to assess the plausibility of a pathway. Studies by Hommes, Ellen, & Seijger (2018) and Soria-Lara & Banister (2017), indicate that the following indicators are important for the feasibility of pathways:

- Power: The degree to which organizations (regional institutions, local institutions, citizens, private sector, governments) are responsible for implementing measures (Hommes, Ellen, & Seijger, 2018; Soria-Lara & Banister, 2017). The more organizations are involved, the less feasible a measure is. Because the more organizations are involved, the greater the organizational consequences or the more partnerships are needed for implementation and a higher degree of renewal of the measure in relation to existing arrangements. This is also called institutional complexity (de Bruin et al., 2009).

- Motivation/cooperation: The degree to which the responsible organizations are motivated and willing to cooperate to implement the measures (Hommes, Ellen, & Seijger, 2018).
- Resources: The degree to which the measure is feasible in terms of finance, knowledge and time (Hommes, Ellen, & Seijger, 2018; Soria-Lara & Banister, 2017).
- Dependence: The degree to which the measure is dependent on other changes in political, social, and economic structures (Hommes, Ellen, & Seijger, 2018; Soria-Lara & Banister, 2017).

A cost-benefit analysis (CBA) can be valuable for the evaluation of pathways in relation to their socio-economic rationale, the economic feasibility (Haasnoot et al., 2019). In a CBA, the costs and the benefits are quantified and assessed for each pathway. The financial and non-financial effects of a measure are compared with the effects of a 'business as usual' scenario in which the current policy remains unchanged. An example of a CBA in the context of soil subsidence is in Box 2.

Box 2: Example of CBA in context of soil subsidence
Van Hardeveld et al. (2018) used a CBA to assess the spatial and temporal physical effects of three water management strategies that drive soil subsidence and land use. The three strategies were compared with the "business as usual" scenario in which the current management is continued unchanged. The three strategies are:

1. Progressively higher water levels
2. Lower water levels
3. Current water levels with field drainage

Strategy 1 leads to a decrease in income from dairy farming. At the same time, soil subsidence decreases, leading to positive economic effects for other stakeholders. This result is mainly due to a reduction in management costs for the water system, roads and sewerage. Strategy 2 has the opposite effect: revenues for dairy farming and soil subsidence both increases. The effects of strategy 3 are more evenly distributed, with positive economic effects for all stakeholders. However, in order to implement this management strategy, it is also necessary to compensate for the negative economic effects of the field drainage itself, which will reduce the overall economic effect of the affected stakeholders.

CBA could also be combined with a Multi-Criteria Decision Analysis (MCDA), either by using CBA as one component of a wider MCDA or by complementing CBA with an MCDA of non-financial values (Van Hardeveld et al., 2018). A MCDA is a framework for supporting complex decision-making situations with multiple objectives that stakeholders and/or decision-makers value differently (Belton & Stewart, 2002). Therefore, it can be a valuable tool to identify the motivation and dependence of stakeholders (Saarikoski et al., 2016).

2.6. Plausibility, an analytical framework

The analytical framework (Fig. 5) depicted below shows how the plausibility of a pathway will be assessed in the course of this study. Suitability and feasibility jointly determine the plausibility of a pathway. For feasibility, four indicators are used: power, motivation/cooperation, resources and dependency.

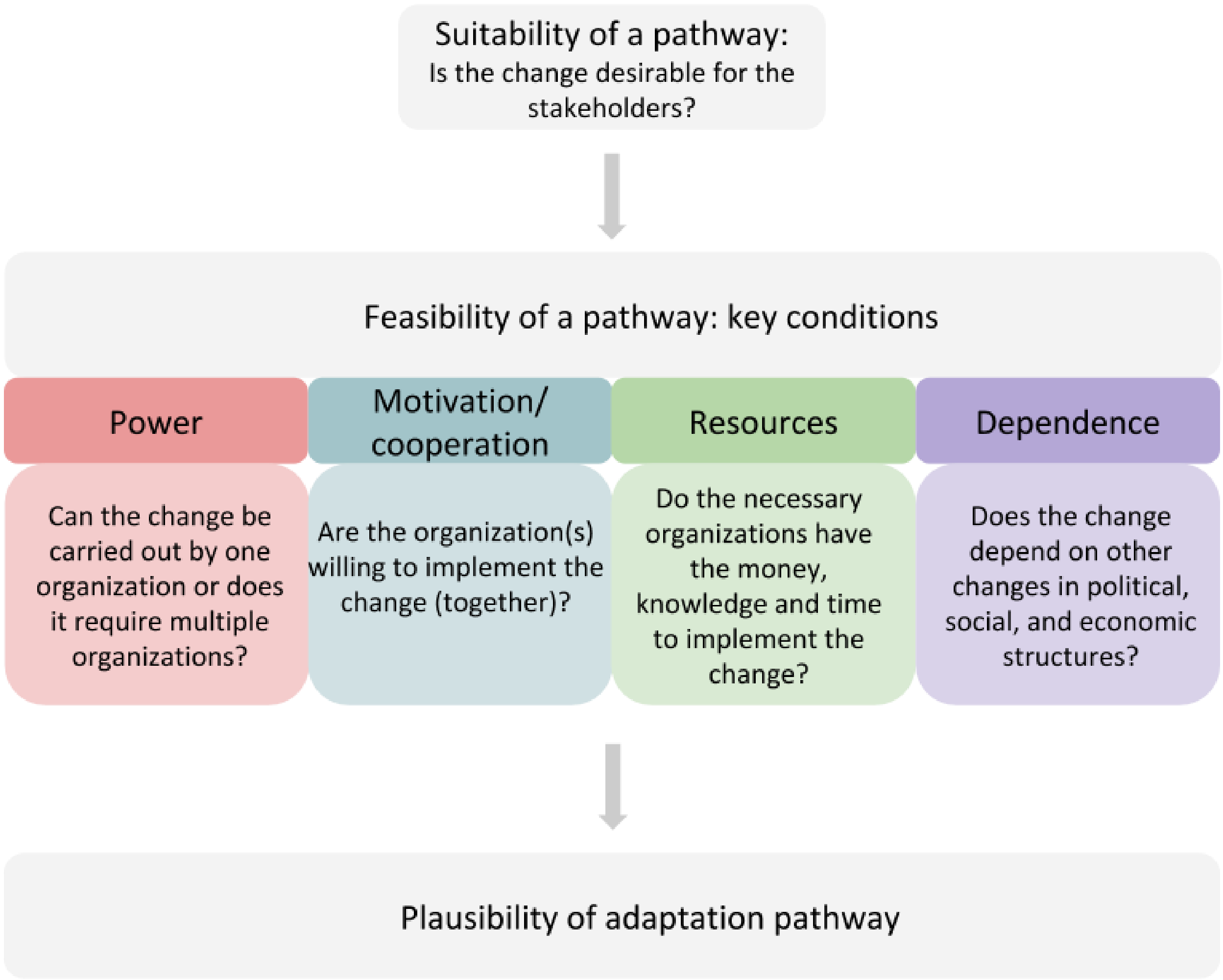

Figure 5: Analytical framework.

2.7. Conclusion

The scenarios used in this study could be regarded as an 'end goal', with transition pathways being the most suitable method. However, adaptation pathways have been chosen for this study because this method ensures robustness and adaptability. These elements are important for the future. Instead of deciding the one or two 'best' strategies now, different measures are considered, which makes the approach more flexible. This is important because the effects of climate change on the rate of soil subsidence and the effects on droughts and floods are still uncertain. Adaptability is therefore crucial. The scenarios used for this study, are explained in the next chapter.

3. Case study

3.1. Introduction

In this chapter, a description of the Amstelscheg is presented. Subsequently, the scenarios of Stedenbouw & Landscapes (2019) are explained.

3.2. Description of the Amstelscheg

In this section, the history, functions, challenges and landscape developments of the Amstelscheg are described.

3.2.1. History of the Amstelscheg

Figure 6: Map of the Amstelscheg (Westerink et al., 2016)

The Amstelscheg is an area in the Green Heart, between Amsterdam and Amstelveen (Fig. 6). Around 4000 B.C. the ice caps had completely melted and the rise in sea level stopped. Behind a series of sand barriers, a stretched peat marsh was formed. In the late tenth or eleventh century the first farmers moved into the peat area (Abrahamse et al., 2012). In the sixteenth century, peat extraction for commercial purposes was also carried out. Nutrient-poor peat such as peat moss was more suitable for this purpose, because little ash remained after combustion. The Rondehoep was never used for peat extraction, because the peat there contained more wood residues and produced poorer peat. The Rondehoep is therefore still a peat-polder ('veenweide'). The Bovenkerkerpolder is used for peat extraction and has been dry milled. This is a polder ('droogmakerij'), and is therefore located lower than, for example, the Rondehoep (Fig. 7) (Abrahamse et al., 2012). The Middelpolder near Amstelveen and the Holendrechter polder to the east of Ouderkerk aan de Amstel were also used for peat extraction and were dry milled in the second half of the 19th century (Fig. 7) (Provincie Noord-Holland, 2018). A more detailed description of the history of the Amstelscheg can be found in Appendix B.

3.2.2. Functions of the Amstelscheg

Many functions come together in the Amstelscheg: living, recreation, agriculture and nature. The proximity of Amsterdam also makes it an interesting area, as residents of Amsterdam make extensive use of the area for recreation. The landscape is still largely agricultural, but the Amstelscheg is becoming increasingly important as a recreational landscape, especially for cyclists and runners. Furthermore, the Amstelscheg is part of the Nature Network of the Netherlands (NNN), it is largely a meadow bird habitat and there are a number of ecological connecting zones (Provincie Noord-Holland, 2018).

3.2.3. Challenges of the Amstelscheg

The Amstelscheg storage basin normally has an open connection with the North Sea Canal, the IJ, the Amsterdam-Rhine Canal and the city waters of Amsterdam. The system drains into the North Sea. The storage capacity of the Amstelscheg basin is little and therefore floods are very well possible. The Rondehoep has therefore been designated as an emergency overflow area. At high tide, this peat-polder can be flooded with a regulated stream flow, to prevent flooding elsewhere. The chance that the Rondehoep will actually be used as an emergency overflow area is less than once every 100 years (Stedenbouw & Landscapes, 2019).

In addition, increasing drought is also a challenge for the Amstelscheg. It is mainly the salinization issue that requires attention. The deeper the polder and the more towards the coast, the stronger the saline seepage from the subsurface. The saline seepage is usually combated by letting in large quantities of fresh water through the basin. For every m^3 of saline seepage water, 10 m^3 of fresh water is needed to combat salinization. This is particularly important for agricultural production. This is because there is less fresh water available in long dry periods and because this smaller supply is used as a priority for drinking water and irrigation, for example (Hoekstra et al., 2014).

Soil subsidence in the area varies depending on the degree of reclamation, type of soil and land use. In the places where a clay deck is present, such as along the edges of the Rondehoep, soil subsidence is approximately 3 mm/year. On peat soils without a clay deck, soil subsidence can be more that 1 cm/year (Stedenbouw & Landscapes, 2019) .

Another challenge is the increasing urbanization pressure from Amstelveen and Amsterdam. If this urbanization will continue, especially the narrowest northern part of the Amstelscheg, above the A9 motorway, will start to densify. This will affect landscape, spatial and cultural-historical values (Tijs, 2013).

Figure 7: Elevation map of the Amstelscheg. Red circles indicate a peat-polder, yellow circles a polder.

3.2.4. Landscape developments in the Amstelscheg

At the end of 2011, the province of North Holland, the municipalities of Amsterdam, Amstelveen and Ouder-Amstel, the districts of Amsterdam South, Amsterdam South-East and East, and the RWA AGV established the Amstelscheg Area Perspective. The focus was on four themes:

- Strengthening the rural area
- Reinforcement of landscape characteristics, in particular the openness of the landscape
- Increasing accessibility
- Programs for e.g. recreation and agriculture

The governments have agreed to include these principles in the provincial structural concept and the zoning plans for the rural area (Abrahamse et al., 2012).

In the Structural Concept Amsterdam 2040 the ambition is formulated to keep the Amstelscheg green, to make it more accessible and attractive for recreation. The focus is on maintaining the agricultural sector, which safeguards the openness of the landscape and respects cultural-historical values. In addition, space is provided for functions such as recreation and nature. Large-scale industrial or agricultural developments must be prevented (Tijs, 2013).

3.3. Scenarios for the Amstelscheg

Given these challenges for the Amstelscheg, Stedenbouw & Landscapes (2019) have explored the effects on the landscape if current policy continues until 2050 (reference) and have made two future land use scenarios for the area. The plausibility of these scenarios will be assessed based on interviews with the key stakeholders. Below, the scenarios are summarized. Some details of the reference, the production landscape and the nature landscape scenarios can be found in Appendix B. For more background information on the study conducted by Stedenbouw & Landscapes (2019), see section 1.3.

3.3.1. Reference scenario

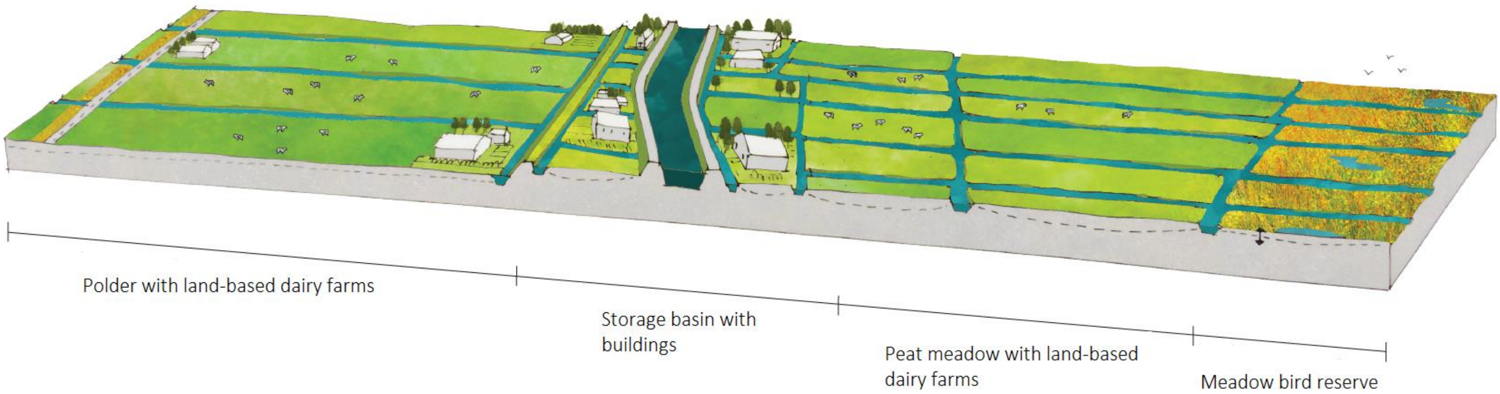

Figure 8: Cross section of the landscape in the reference scenario (Stedenbouw & Landscapes, 2019).

The reference scenario serves as a 'baseline measurement' for the comparison of the developed scenarios.

Soil subsidence

Soil subsidence in the area varies depending on the degree of reclamation, the type of soil and the land use. On average, a soil subsidence of 7 mm/year for the peat soils in the Amstelscheg is assumed. This would indicate a total soil subsidence of 21 cm in 2050. On peat soils without a clay deck, soil subsidence can exceed 1 cm/year. The annual costs as a result of soil subsidence for RWA AGV are estimated at 37 million euros, for sewers, dikes and roads 22 million euros and for houses more than 3 million euros.

Water requirement

In 2018, there was an official national water shortage in which emergency measures were taken in various places. The so-called "verdringingsreeks" was used for this. This determines which user functions take precedence in the distribution of (fresh) river water. The first priority is safety and the prevention of irreversible damage, for example by settling and subsidence of peat. Agriculture and nature have the lowest priority. It is expected that water shortages will occur more frequently in the future, which may lead to insufficient availability of fresh water for agriculture and nature. Due to increasing drought, the water demand in the Green Heart will increase by 20% if policy remains unchanged until 2050.

Water quality
The ecological water quality in the Ouderkerkerplas and the Amstellandboezem is "inadequate" and "poor" in the canals of the Bovenkerkerpolder, Middelpolder and the Rondehoep (Waterschap AGV, 2020). Table B1 in appendix B, provides detailed information on the biological and chemical factors on which this water quality is based. The goal for 2027 is that the ecological water quality in all the above waters should be good. AGV hopes to achieve this, among other things, by cooperating with the agricultural sector and thereby reducing the leaching of manure and plant protection products.

Greenhouse gas emissions
The total emissions from current land use are approximately 84,000 tons of CO_2 per year. This is in line with what a mature Dutch forest of more than 19,000 ha records each year: an area more than four times as much big as the whole Amstelscheg (Schelhaas et al., 2017).

3.3.2. Production landscape scenario

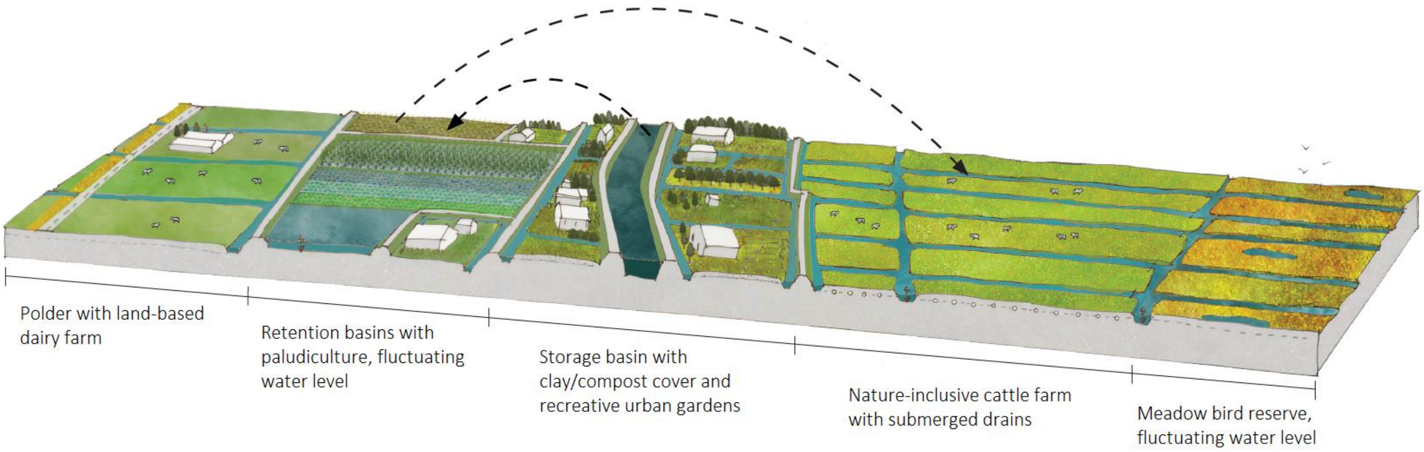

Figure 9: Cross section of the landscape in the production landscape scenario (Stedenbouw & Landscapes, 2019). The arrows indicate the transport of water. Top arrow: water from retention basins to farm with submerged drainage. Bottom arrow: water from storage basin to retention basins (Stedenbouw & Landscapes, 2019).

The three main measures in this scenario are:
1. Construction of water retention basins in polders.
2. Switch to paludiculture in polders.
3. Implementation of submerged drainage in peat-polders.

Effects on soil subsidence
Various practical tests have shown that submerged drains can reduce soil subsidence by about 50% (Hoving et al., 2018). Groundwater level in the plots is kept high in summer and therefore less oxygen can enter the soil. By connecting drain pipes to a closed water reservoir, the groundwater table can be regulated with a pump independently of the ditch water level. The reduction in soil subsidence can rise to more than 60%. Soil subsidence will be completely stopped in the polder areas with residual peat that are set up as a retention basin and are in principle permanently inundated.

Effects on water requirement
If the ditch level falls below the minimum level, water is replenished from the retention basin in the polder. The retention basin is fed by rainwater, seepage water and discharge from the adjoining part of the polder. Due to the seepage and the discharge, water supplies are also available in dry summers and an empty retention basin is prevented. It is estimated that with sufficient surface retention area the inlet requirement of the peat areas can also be reduced to zero in dry summers. The edge zone of the Bovenkerkerpolder is approximately 400 ha in size; this results in 4 million m^3 of water storage at 1 m level fluctuation.

Effects on greenhouse gas emissions
As a result of the reduced soil subsidence, CO_2 emissions from the peat areas will also decrease. If zero emissions for the retention basins (500 ha) are assumed, an annual emission of approximately 20,000 tons of CO_2 equivalents is expected, a reduction of 34,000 tons, for the remaining 3,000 ha of peat area. As a result of the extensification of agriculture and the reduction in the number of cows and the amount of milk produced (by approximately 35%), an additional reduction in CO_2 emissions is expected, with approximately 10,000 tons of CO_2 annually.

With a reduction of 45,000 tons of CO_2, an emission of 39,000 tons of CO_2 per year remains. This corresponds to a mature Dutch forest of over 9,000 ha records in a year, which is still double the area of the entire Amstelscheg.

3.3.3. Nature landscape scenario

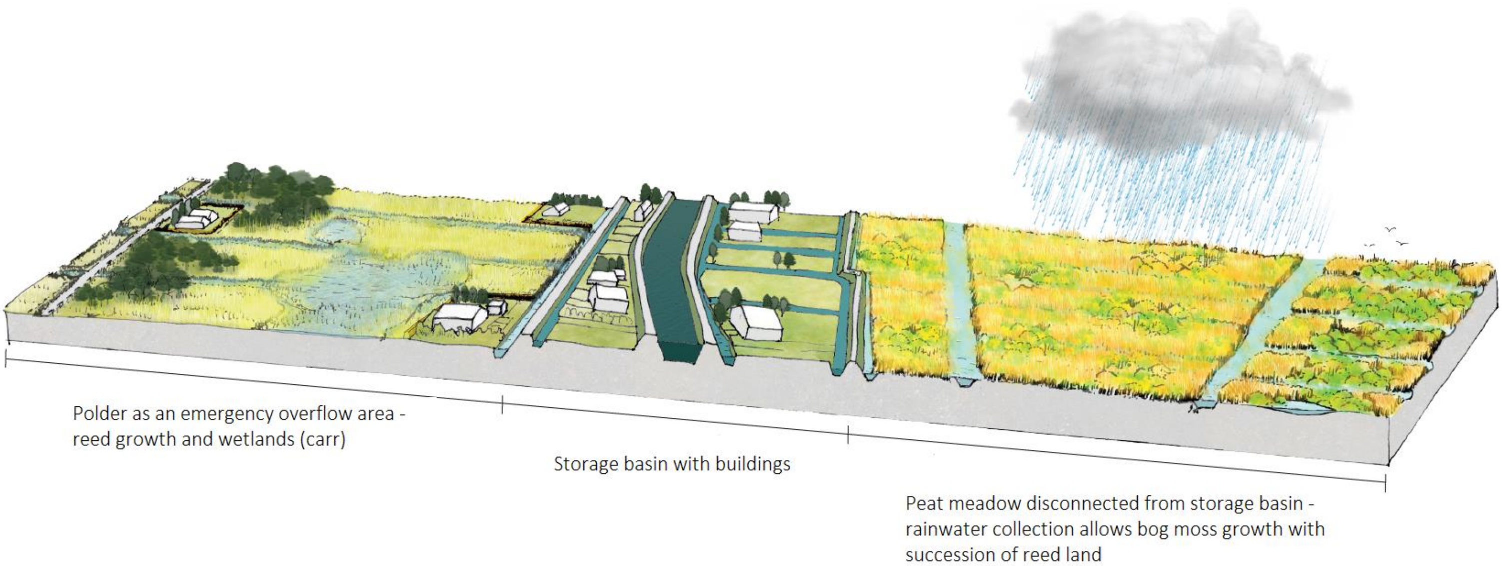

Figure 10: Cross section of the landscape in nature landscape scenario (Stedenbouw & Landscapes, 2019).

The three main measures in this scenario are:
1. Active rewetting for peat bog in peat-polder.
2. Farmers changing towards nature management.
3. Farmers leaving the area.

This scenario assumes the maximization of biodiversity and active peat recovery, by transforming the current land use from agriculture to nature. The scenario focuses not only on meadow birds, but on restoring all ecological components of the peat landscape, including rainfed raised peat bog. This peat bog component has almost completely disappeared from the Green Heart due to extraction and reclamation. Peat formation captures CO_2 and can convert soil subsidence into soil rise. In addition, it retains a lot of water, making water shortages and large peak discharges a thing of the past.

Effects on soil subsidence

In this scenario, the soil subsidence is completely stopped and converted into soil rise. Practical tests in the Ilperveld showed that a peat layer of 8 to 12 cm had already formed within 4 years after sowing peat moss on bare peat soil. The site was kept wet with rainwater from a separately constructed collection basin. In the first 4 years, the wet peat moss fields were mowed 3 to 4 times a year with a lightweight mower equipped with extra wide wheels.

Effects on water requirement

In this scenario, the external water requirement is reduced to zero. After all, the peat areas are completely fed by rainwater. The sponge effect of the peat ensures that the soil remains water-saturated and does not degenerate. In open water areas, slight level fluctuations may occur, allowing floating islands to fluctuate along and remain sufficiently wet.

Effects on greenhouse gas emissions

Estimates of the net sequestration of greenhouse gases due to peat formation vary widely. Not much research has been done on this. The picture is that CO_2 is captured, but that there may still be emissions of methane and nitrous oxide. In part, these emissions appear to be caused by past fertilization, and could therefore be a temporary effect. The study in the Green Heart also shows that methane and nitrous oxide emissions are smaller than the capture of CO_2 and that there is a net capture of CO_2 equivalents. Based on the figures from that study, wetting of all peat soils in the Amstelscheg will capture 19,000 tons of CO_2 equivalents annually, a reduction of 73,000 tons.

In addition, CO_2 emissions from dairy farming will decrease by 30,000 tons. The total reduction in emissions therefore amounts to 103,000 tons of CO_2 equivalents. The annual commitment of 19,000 tons of CO_2 equivalents corresponds to those of 4,600 ha of forest, roughly the same area as the Amstelscheg.

4. Stakeholder opinions on suitability and feasibility of the scenarios

4.1. Introduction

In this chapter, the key characteristics of the stakeholder network are identified, the results of the comparative assessment are reviewed, and the most plausible pathway is identified.

4.2. Key characteristics of the stakeholder network

Based on a stakeholder analysis (Appendix C), a stakeholder network was created with a selection of the most important stakeholders (Fig. 11). The representatives of each of these stakeholders were interviewed. The interview questions can be found in Appendix F.

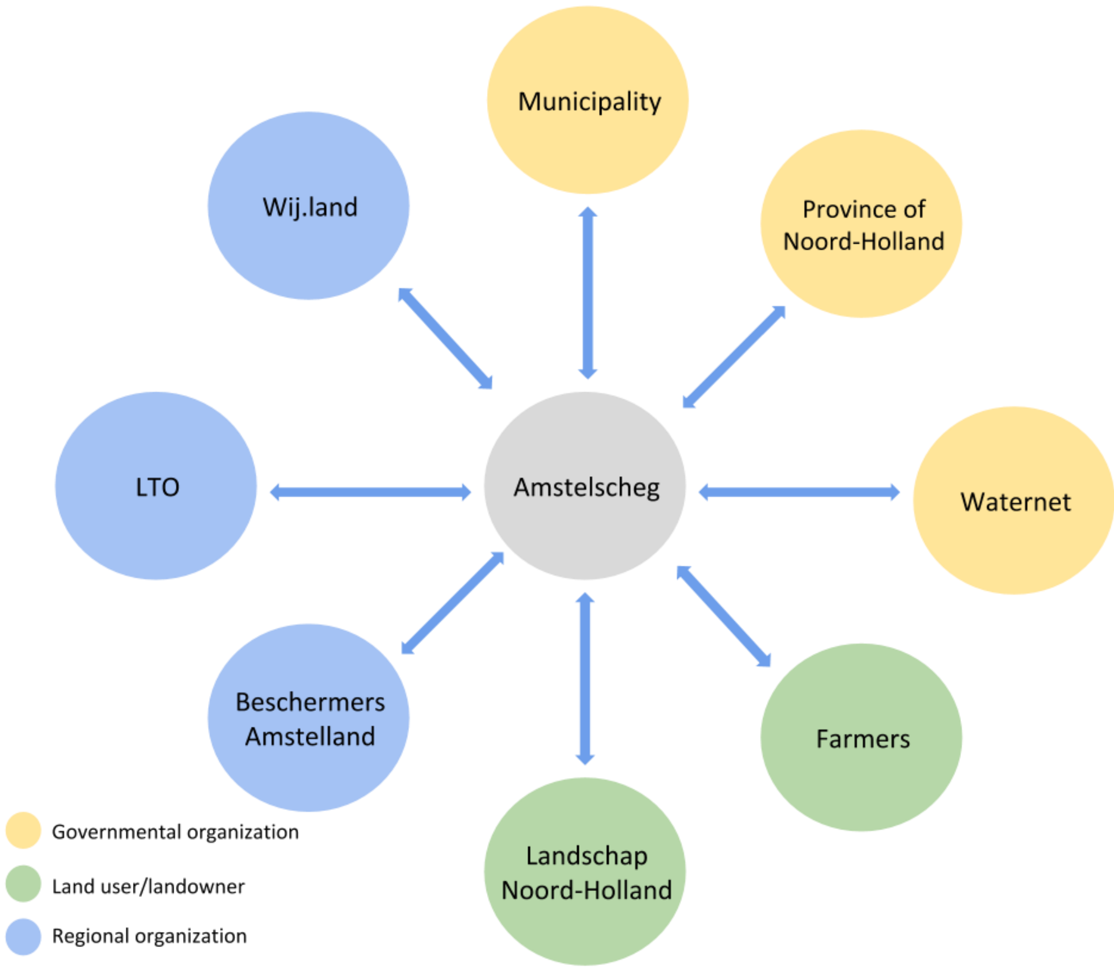

Figure 11: Stakeholder network

There are several governmental organizations active in the Amstelscheg: municipality of Ouder-Amstel, municipality of Amsterdam, municipality of Amstelveen, Province of Noord-Holland, RWA AGV and Waternet. These governments are all related to each other. The province has decision-making power in spatial planning for example. The province considers all factors, such as water, housing, agriculture and nature, in a coherent manner, and thereby develops regional spatial-economic policy and coordinates on issues that transcend municipal boundaries (Provincie Noord-Holland, n.d.). In addition, the province supervises the RWA and the municipalities. Each year, the municipalities have their budgets and annual accounts approved by the Provincial Executive (Rijksoverheid, n.d.). Waternet works on behalf of RWA AGV. If a dike needs to be raised, AGV takes the decision and Waternet executes the decision (Waternet, n.d.).

The most important landowners and land users in the Amstelscheg are farmers and Landschap Noord-Holland (Landscape North-Holland). Farmers, especially dairy farmers, manage the largest proportion of land in the Amstelscheg. In 2013, there were about 50 dairy farms active in the Amstelscheg, and a similar number of farms focusing on other branches of livestock farming (Westerink et al., 2016). The initiative the 'Boeren van Amstel' consists of 21 farmers who are engaged in agricultural nature management with herb-rich grasslands, an ideal area for meadow birds to breed. The habitat of the meadow birds is protected by mowing large parts of the land only after the breeding season. Landschap Noord-Holland manages 160 hectares of meadow bird reserve in the core of the Rondehoep and a part in the Middelpolder.

There are also several foundations and organizations active in the Amstelscheg. The LTO (Netherlands Agricultural and Horticultural Association) is one of those organizations, it is the interest group for farmers. The foundation Beschermers Amstelland (Protectors Amstelland) stands for the preservation of the Amstelscheg as an open and accessible, vital agricultural area with great natural values in which to farm and recreate with respect for landscape, nature and cultural history. Another organization active in the field of sustainable agriculture is Wij.land, an organization that enables farmers to test solutions e.g. in the field of natural soil management, wet cultivation, strengthening biodiversity and closing cycles on their own farms in pilot projects.

One of the interviewees, Karres & Brands, is not included in the stakeholder network. They were interviewed because of their research project "Manifest van de Scheggen". A project in which they made a future-proof proposal for the Amstelscheg, as part of a manifesto with seven other proposals for the other green areas surrounding Amsterdam (ARCAM, n.d.).

4.3. Perceptions on the reference scenario

Table 2 shows an overview of the current challenges, and the stakeholders that experience this challenge as a problem. Below the table, the challenges are further explained.

Table 2: Overview of the stakeholders that experience certain challenges as a problem.

Challenge → Stakeholder ↓	Soil subsidence	Drought	Saline seepage	Costs of the consequences of soil subsidence
Waternet	X	X	X	X
Farmers	X	X	X	
Landschap Noord-Holland	X	X		
Municipality of Amstelveen	X	X		
Province of Noord-Holland	X			
Beschermers Amstelland	X	X		
Wij.land	X	X		

Soil subsidence
Soil subsidence is acknowledged by all stakeholders, and farmers experience a yearly subsidence of 8 - 10 mm. However, there are differences in the perception of how serious the problem is. One of the farmers, located in the Rondehoep, stressed that ten years ago no one was talking about soil subsidence and moreover, it is a process that has been going on for hundreds of years. In addition, the ground level in the Rondehoep is now about -2.5 m NAP, and in the province of South-Holland polders are at -6 m NAP and it is still possible to farm there. But in addition to physically experiencing soil subsidence, there is also increased pressure from society to take measures against soil subsidence. Therefore, farmers in the Rondehoep have formed a team that thinks about the future of dairy farming. Their goal is to reduce soil subsidence by about 50% over the next 25 years. Over the past 100 years, soil subsidence has been estimated by a local farmer at 80 cm (Interview 2, 2020).

In addition, Waternet has decided to adjust its policy regarding water-table decisions because of soil subsidence. Waternet has decided that from 2030, only 75% of the soil subsidence will be followed by a lowering of the water level, while facilitating the current land use. However, in the distant future the non-automatic lowering of water levels may mean that livestock farming will no longer be possible in parts of the peat meadow area. Land users will therefore have to learn to live and work with an annually decreasing level of drainage (Interview 1, 2020).

Drought
In the Bovenkerkerpolder, which is a polder (droogmakerij), soil subsidence is a less of a problem than in the Rondehoep. The Municipality of Amstelveen also indicated that soil subsidence affected infrastructure, such as peat dikes (Interview 4, 2020). This is mainly due to dehydration in times of little rainfall. This has become more and more common in recent years, and all stakeholders endorse this. That is why several stakeholders are arguing for a fundamental change in the water system. Foundation Beschermers Amstelland believes the focus should be on water retention in the area since drought is not just an incident anymore (Interview 7, 2020).

Another problem related to drought is that the meadow bird reserve in the Rondehoep is getting drier, which is not the optimal condition for the meadow birds. On the contrary, the water level should be higher in this area (Interview 7, 2020). Landschap Noord-Holland also indicated that sufficient water is needed for the reserve, otherwise there is a problem for the meadow birds (Interview 5, 2020).

Saline seepage
In a few polders in the Amstelscheg, such as the Bovenkerkerpolder, there is upward saline seepage. According to Waternet, this will occur in many more places if soil subsidence continues in the coming years. And once it happens, the only solution is to steer the salt flows in such a way that they cause as little damage as possible in the rest of the area. That comes down to pumping it away to the Amstel as quickly as possible and then towards IJmuiden. Another possibility is being investigated by Waternet, where the saline seepage is pumped to a desalination plant and then the water could be used as drinking water. This would reduce the need for flushing with fresh water from Lake IJssel, thus reducing the demand for water (Interview 1, 2020).

The farmers in the Amstelscheg are also worried about the increasing saline seepage and its effects on the water quality. The polders, such as Mijdrecht-Wilnis and the Bovenkerkerpolder, store a lot of brackish water. This all ends up in the storage basin, in the Waver and in the Amstel. In the Rondehoep, quite a lot of water from the storage basin is let into the peat-polder and as a result, the quality of the peat-polder water deteriorates. In spring, the quality is still good because a lot of rain has fallen and little water has been let in, but as the summer progresses, it becomes saltier. According to the farmers, water quality needs to be improved, it is important for the overall quality of the peat-polder (Interviews 2 & 3, 2020).

Costs of the consequences of soil subsidence
For Waternet, the costs of the consequences of soil subsidence are also an important reason to take measures against it. Currently, water management is already expensive, and this will only increase due to soil subsidence. In the coming decades this will run into an increase at the level of percentages, but in the second half of this century this will run into the double digits. Then the level differences will become so large that it will be necessary to invest in flood defenses. Waternet wants to be one step ahead of that (Interview 1, 2020).

4.4. Perceptions on the production landscape scenario

Table 3 shows the multi-criteria framework for the production landscape scenario. Subsequently, for each indicator it is explained why this score is given.

Table 3: Multi-criteria framework for the plausibility of the production landscape. The size and complexity of a measure or policy instrument to be implemented was scored on a scale from 1 to 5 (1 = easy to implement, 5 = difficult to implement).

Indicator	Production landscape measures		
	Construction of water retention basins in polders	Switch to paludiculture in polders	Implementation of submerged drainage in peat-polders
Suitability	2	5	2
Power	2	1	1
Motivation/ cooperation	2	4	3
Resources	2	3	3
Dependence	2	4	3

4.4.1. Suitability

The construction of water retention basins is seen as desirable by farmers and the RWA. But the switch to paludiculture is currently considered undesirable by farmers. In addition, the implementation of submerged drainage is seen as reasonably desirable, a few farmers would be willing to start a pilot.

4.4.2. Feasibility

Power
Waternet will play an important role in the construction of water retention basins. But also, farmers, since the basins will most likely be implemented on their land. One possibility would be for the RWA to buy land and then lease it out under certain conditions, for example the implementation of water retention basins. Farmers are important for the other measures as well. Switching to paludiculture, is up to the farmers, but Wij.land can support this transition by supporting pilots and substantiating the business case, thereby making the switch more attractive. Submerged drainage must also be implemented by farmers.

Motivation/cooperation
Waternet doubts whether the retention basins will work because of the combination with paludiculture and the drier summers in the Netherlands. The evaporation will be considerable. If the water from the basins is then also used to supply adjacent areas with water, the fluctuations become even more pronounced. If the basin is too small, it will be empty very quickly. If the idea would be implemented with a lake, a large surface that can fluctuate 1.5 meters in water level, it could become interesting. The disadvantage is that for the cultivation of cattail, reed or peat moss, that margin in water level is not possible. The question is therefore whether the retention basins and paludiculture

should be combined, or whether this should be two separate strategies. Another thing to consider are the drier summers the Netherlands is experiencing the last years, weeks without rain and high temperatures will then ensure that the basin will soon be depleted (Interview 1, 2020).

Farmers seem to be looking positively at the implementation of water retention basins. Although agricultural land is lost, it allows to store much more freshwater. In addition, it can also have a positive effect on the water quality of the ditch water, by reducing saline seepage (Interview 2 & 3, 2020). It also seems to be a realistic measure. Every year there are farmers who quit, and then agricultural land becomes available. In the long term, grasslands can be used for other crops, especially those that are very wet and therefore less suitable for dairy farming (Interview 2, 2020). But, the combination with paludiculture is viewed less positively. There is little motivation amongst farmers for paludiculture, and this is mainly because there is no business model yet (Interview 3, 2020).

Submerged drainage is another measure from the production landscape scenario. Farmers want to realize pilots on the short term. Uncertainty about the effectiveness particularly on the long term (10 - 20 years), its effect on the soil during summer, and costs are factors that prevent them from implementing it on a large scale (Interview 2, 2020).

Resources

Of all types of resources, the lack of knowledge seems to be the main problem. Farmers indicate that research into paludiculture is still in its early stages. Currently there are a few plots of land under research, to see if a business model could be realized. But before farmers are ready to invest in paludiculture, more knowledge is needed and a business model needs to be developed (Interview 3, 2020). Innovation Program Peat (Innovatieprogramma Veen, IPV) investigates the opportunities for agriculture under wet conditions. Currently, paludiculture is still in a premature phase, both for crop- and harvest optimization, and regarding the maturity of the market. The general awareness of wet crops, and their commercial potential, is still low on the market. But, the IPV identifies three crops with commercial potential: cattail, peat moss and azolla. It is necessary to research which variety should be selected, how to grow and harvest it optimally with different water levels, before the operation can be brought to scale (Van Duursen et al., 2016).

In addition, there are still quite a few knowledge questions regarding the effectiveness of submerged drainage, as explained under “motivation”. There are two main topics according to the Province of North-Holland: freshwater availability and to what extent it sufficiently counteracts soil subsidence, or whether it is just a temporary solution (Interview 6, 2020).

Waternet indicated that public opinion has a strong influence on their mandate and willingness to support and change the water management strategy and the resulting land use in the area. However, they will first carry out thorough research into, for example, the implementation of water retention basins, as it still has some risks regarding water availability (Interview 1, 2020). Waternet, in collaboration with a farmer, is already conducting research into paludiculture. Waternet will look at water use, water quality, effects on the soil and the release of chemical substances such as phosphate. The farmer will look at how to grow and harvest the wet crops (peat moss, reed and cattail) optimally and the business model (Waternet, 2019).

Dependence

Waternet's changing policy of no longer automatically lowering water levels from 2030 onwards will have consequences for farmers. This policy may increase the pressure to take measures. Until then, farmers will have to show that they have taken appropriate measures to prevent soil subsidence, in return Waternet will take appropriate measures to adjust the water level (Interview 1 & 3, 2020).

Developments around paludiculture are very important for the implementation on a large scale, as this is still in the premature phase. In addition, business models for paludiculture are very important for farmers. The implementation of paludiculture on a large scale therefore depends on how quickly developments in this area will take place.

As indicated by Waternet, public opinion strongly influences their mandate and willingness to support and incur changes in the water management strategy and consequent land use in the area. Farmers also operate partially in response to public opinion, but a large proportion of them also understand that changes need to be implemented in the dairy farming sector (Interview 1, 2020).

Another important aspect of the problem concerning peat meadow areas is CO_2-emission. According to the Climate Agreement, the intention is to reduce 1 megaton of CO_2-emissions for the peat meadow areas in the Netherlands. The Province of North-Holland must submit plans to the Ministry of Agriculture, Nature and Food Quality, to reduce CO_2 emissions from peat meadows. This may also lead to changes in the water management strategy and the resulting land use in the area (Interview 6, 2020).

4.5. Perceptions on the nature landscape scenario

Table 4 shows the multi-criteria framework for the nature landscape scenario. Subsequently, for each indicator it is explained why this score is given.

Table 4: Multi-criteria framework for the plausibility of the nature landscape. The size and complexity of a measure or policy instrument to be implemented was scored on a scale from 1 to 5 (1 = easy to implement, 5 = difficult to implement).

Indicator	Nature landscape measures		
	Active rewetting for peat bog in peat-polder	Farmers leaving the area	Farmers changing towards nature management
Suitability	4	5	4
Power	2	3	2
Motivation/ cooperation	4	5	4
Resources	3	5	4
Dependence	4	5	5

4.5.1. Suitability

None of the measures are currently considered desirable. The active rewetting of peat would mean that farmers would no longer be able to continue their current business. The farmers would like to stay in the area and are not planning to leave the area any time soon. In addition, the switch to nature management is not desirable at the moment, all stakeholders prefer to preserve agriculture in the area.

4.5.2. Feasibility

Power

Waternet is responsible for raising water levels and active rewetting of peat. And since most of the land is farmland, the farmers are also important for this measure. Waternet will also play an important role in the design of the area in order to retain as much rainwater as possible. Farmers will have to leave the Amstelscheg if they wish to continue their current farming activities, such as dairy farming.

This could be achieved by means of a subsidy scheme or buying-out by, for example, the RWA or the national government. The province could also play a role by providing land somewhere else for these farmers. Another possibility for farmers would be to change their business model towards nature management.

Motivation/cooperation
Waternet has doubts about this scenario. This scenario asks for a precipitation surplus, but with climate change and influent seepage from the elevated peat meadows towards the polder, it will leak at the bottom. The only way to prevent that, is by turning the polder into water, which is even more extreme than the nature scenario already is. But if this scenario is the outcome of an area planning process and everyone agrees, Waternet will go along with this scenario (Interview 1, 2020).

Farmers also shared their doubts about this scenario. They do not expect the nature landscape to be the result by 2050. The scenario has very far-reaching consequences for the whole area and it will not be beneficial for the meadow birds. Meadow birds prefer short grass and an open landscape, while in this scenario reed and trees predominate. The open landscape is a characteristic for which the area is famous, and with this scenario that would be gone (Interview 3, 2020).

Resources
This scenario would cause the income stream of Waternet to change. Water management is expensive, whether it is about agriculture or nature. But farmers pay a considerable amount per hectare, and nature conservation pays relatively little. If this scenario would be applied on a large scale, it would therefore have consequences. Residents would probably have to pay a lot more tax, perhaps almost double the amount they pay currently (Interview 1, 2020).

Moreover, it is uncertain whether a carbon credit system will be able to pay for this scenario. The climate could change in such a way that the major food producing regions fail one harvest after another and the price of dairy products could be ten times higher than at present (Interview 1, 2020). Besides, currently there is no carbon credit system, there needs to be a party that pays for the CO_2 that is captured (Interview 4, 2020).

This scenario would also mean that all farmers would be bought out. First, who is going to pay for it? And secondly, who will manage the nature reserves? Discussions are already ongoing about whether biodiversity will be sufficiently conserved. This is partly due to a lack of suitable habitats for animal and plant species, fragmentation due to urbanization and infrastructure, environmental problems such as insufficient water quality, dehydration and high phosphate and nitrogen emissions from traffic, industry and agriculture (Provincie Noord-Holland, n.d.). If more nature areas are added, this will become an even greater task. Moreover, the depreciation of land can become a problem for the party buying the land (Interview 6, 2020).

Dependence
The implementation of this scenario depends on how quickly developments occur. If soil subsidence accelerates as a result of climate change or if climate targets must be met, this scenario can be chosen earlier because of external pressures. The current policy is to reduce CO_2 emissions from peatland by 1 Mton. If the regulations become stricter, the reduction will have to be even greater and more drastic measures will have to be taken.

In addition, it is possible that the municipality of Amsterdam or the municipality of Amstelveen would like to build more houses in the Amstelscheg. This will also have consequences for spatial planning. Another possibility is that the area could also be used more to generate sustainable energy. For example: solar energy, thermal energy or biomass. The nature landscape scenario could then still be an option, these energy sources could be combined with this scenario.

Another influential development is the Dutch nitrogen policy. For example, if this becomes stricter and more farmers are bought out, more nature could be realized. Background information on nitrogen in the Netherlands can be found in Box 3.

Box 3: Nitrogen in the Netherlands
Deposition of nitrogen compounds leads to a reduction of biodiversity in nature. These nitrogen compounds also contribute to reduced air quality and health risks. Dutch emissions of the total amount of nitrogen per hectares are the highest in Europe, almost four times the average value. Dutch nitrogen emissions include 60% emissions of ammonia (NH_3) and 40% emissions of nitrogen oxides (NO_x). Agriculture is responsible for 61% of total nitrogen emissions, this is mainly due to emissions of NH_3 from manure. In addition, road transport (15%), industry (9%), non-road mobile machinery (6%) and households and offices (6%) also contribute substantially to the total nitrogen emissions in the Netherlands (Schollaardt, 2019).

The Dutch government has a nitrogen policy that enables more farmers to retire from farming in order to reduce nitrogen emissions. Those with the highest nitrogen deposition in a Natura 2000 area qualify first. Another measure is that from September 1st, 2020, there will be rules for the maximum amount of protein feed. Feed with a lower protein content will reduce ammonia emissions (Koekkoek, 2020).

4.6. Most plausible pathway

The multi-criteria tables for the two scenarios are shown next to each other below. The sum of all indicators for each measure is also given. The higher the score, the more difficult to implement a measure. The tables show that the plausibility of the production landscape is relatively higher than that of the nature landscape.

Table 3: Multi-criteria framework for the plausibility of the production landscape, including the sum of all indicators for each measure. The higher the score, the more difficult to implement a measure (1 = easy to implement, 5 = difficult to implement).

Indicator	Production landscape measures		
	Water retention basins	Paludiculture	Submerged drainage
Suitability	2	5	2
Power	2	1	1
Motivation/ cooperation	2	4	3
Resources	2	3	3
Dependence	2	4	3
Sum	*10*	*17*	*12*

Table 4: Multi-criteria framework for the plausibility of the nature landscape, including the sum of all indicators for each measure. The higher the score, the more difficult to implement a measure (1 = easy to implement, 5 = difficult to implement).

Indicator	Nature landscape measures		
	Active rewetting for peat bog	Farmers leaving the area	Farmers changing towards nature management
Suitability	4	5	4
Power	2	1	1
Motivation/ cooperation	4	5	4
Resources	3	5	4
Dependence	4	5	5
Sum	*17*	*21*	*18*

The production landscape scenario scores best in terms of plausibility and is preferred by most stakeholders. A more extensive form of agriculture, such as beef cattle that can withstand wet conditions, combined with places where meadow birds can breed, and possibly places where paludiculture is practiced. A roadmap towards this future is visualized in figure 12.

4.6.1. Roadmap towards most plausible pathway

Between 2020 and 2030, the focus will have to be on conducting ***pilots*** and small-scale testing of, among other things, submerged drainage and paludiculture. In addition, a ***risk dialogue*** should be started with all relevant regional partners and municipalities, province and the RWA. This dialogue should make clear how vulnerable the area is to climate extremes and how these can be reduced with concrete measures (Kennisportaal Ruimtelijke Adaptatie, n.d.). Subsequently, an ***implementation agenda*** must be drawn up with agreements about who will do what (Kennisportaal Ruimtelijke Adaptatie, n.d.). Finally, measures must be taken by 2027 to ***improve water quality*** in the Amstelscheg in accordance with the Water Framework Directive (Rijksoverheid, n.d.)

RWA AGV has decided that from 2030 only 75% of the soil subsidence will be followed by a lowering of the water level, while facilitating the current land use will remain the starting point. In the distant future, this may mean that livestock farming in parts of the peat meadow area will no longer be possible. Farmers expect to be able to continue farming up to a drainage depth of 30 - 40 cm (Interview 3, 2020). Appendix D shows example calculations of drainage depth in view of certain policy objectives. From 2044 onwards, drainage depth could start causing problems for farmers.

Between 2030 and 2040, measures can be taken to fundamentally change the ***water system***. In addition to flood safety, the focus will have to be on water retention, drought control and preventing saline seepage. One strategy could be to retain more water in the area during winter, since the cattle will then be in the cowshed. The next step is to assess how to keep enough water for the whole summer period.

When implementing measures, consideration should also be given to opportunities for ***multifunctionality***. A measure can serve several purposes at once, such as a water retention basin that also generates thermal energy, or on which floating solar panels are installed. In addition, new business models for farmers, such as paludiculture, will need further ***research***. Finally, it is extremely important to ***support*** and encourage good, local initiatives. For example, the 'Boeren van Amstel', this initiative has the potential to further expand and really become the showpiece of the area.

Between 2040 and 2050, the main challenge is to assess whether the objectives for 2050 will be achieved. The area must be ***water-robust*** and ***climate adaptive***, and able to respond to extremes such as heavy precipitation and long periods of drought. In addition, annual ***soil subsidence*** must be at least halved. The result is a ***production landscape*** that is a lot more extensive, where more nature is present, and where farmers can continue to farm with a higher water level.

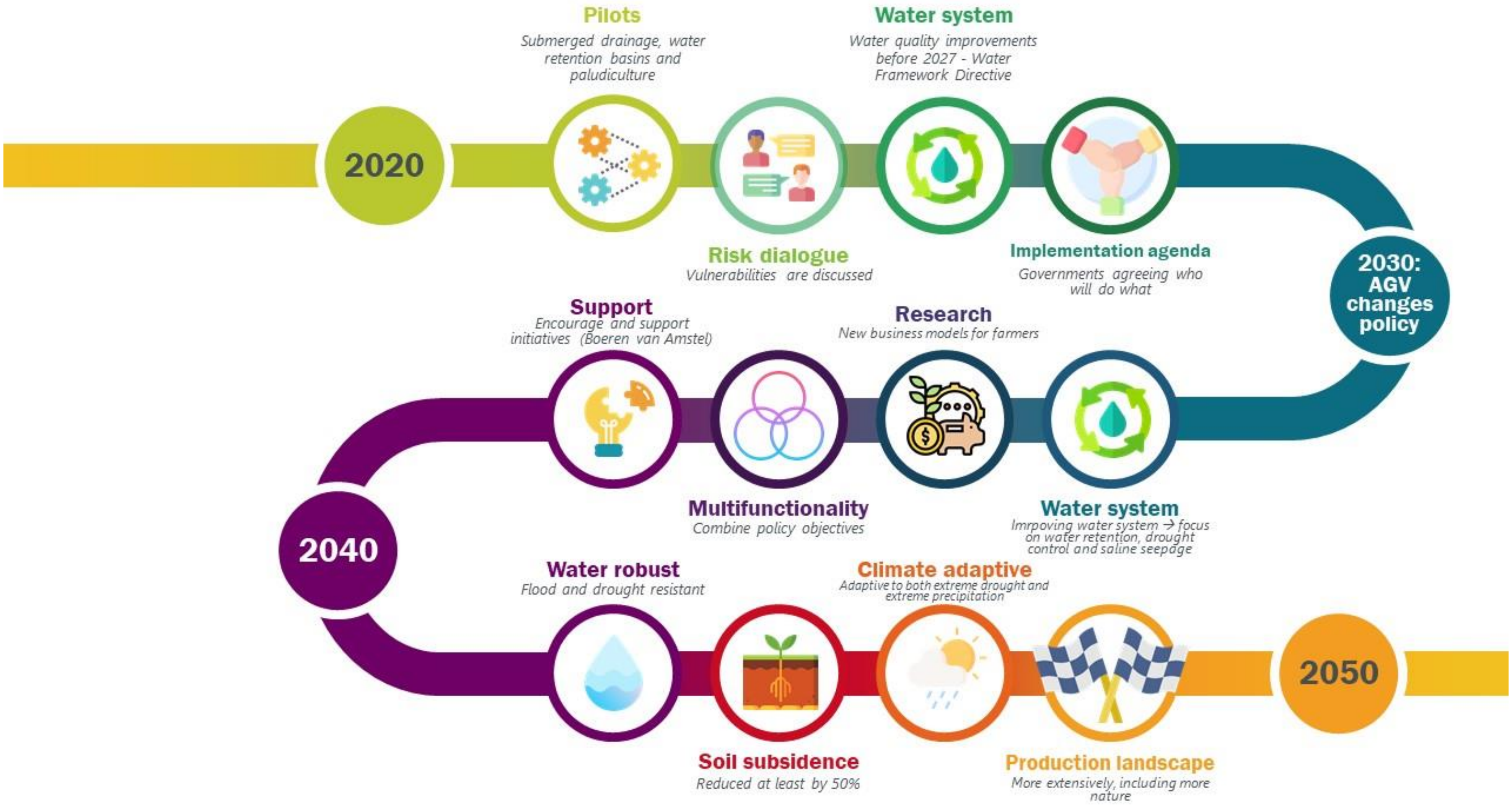

Figure 12: Roadmap for the Amstelscheg.

4.6.2. Adaptation pathway for the Green Heart

Besides a roadmap, an adaptation pathway has been created (Fig. 13) in line with the pathway by Cradock-Henry et al. (2020). The adaptation pathway is based on the information from interviews and policy objectives from RWA AGV. The drainage depth on the x-axis is based on the calculations of drainage depth until 2100 (Appendix D). In case of other scenarios, the anchoring to time changes, the link to drainage depth remains. The adaptation pathway is explained in Box 4.

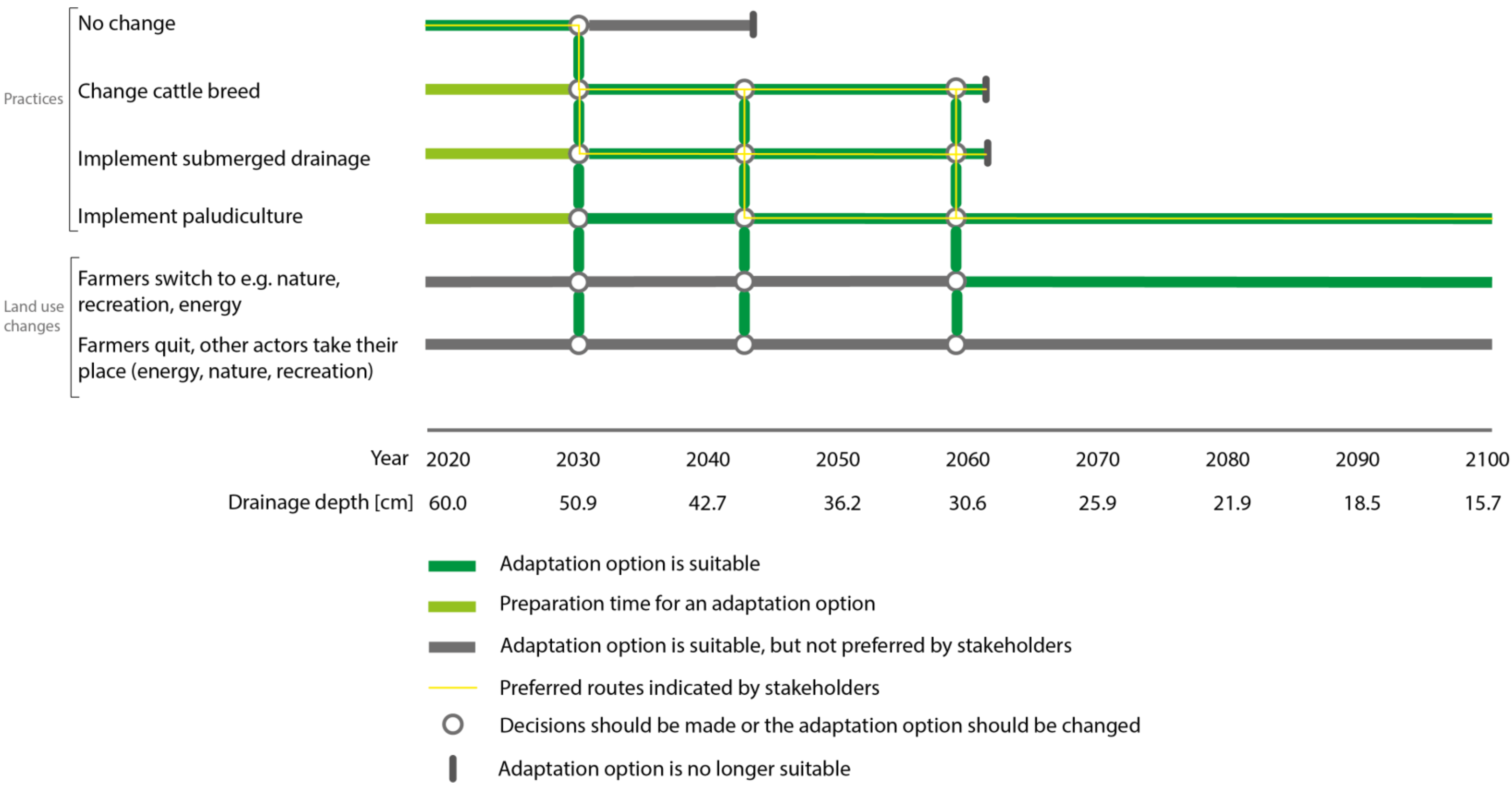

Figure 13: Adaptation pathway for addressing soil subsidence in peatland areas in the Green Heart.

Box 4: Adaptation pathway

In the map, starting from 'no change', an adaptation tipping point is reached in 2044, when the drainage depth falls below 40 cm. The first decision point can be seen in 2030, as a result of the changing policy of RWA AGV. From the first decision point onwards there are five options, three of which are not preferred by the stakeholders (no change and land use changes). The two land use changes and paludiculture should be able to achieve the targets up to 2100. If 'change cattle breed' or 'implement submerged drainage' is chosen, a tipping point will be reached in 2062, when the drainage depth falls below 30 cm. A shift to 'paludiculture' or one of the land use changes will then be necessary to achieve the targets. The least preferred measure is the one where farmers quit and other actors take their place, this measure will remain non-preferred until at least 2100.

5. Discussion

5.1. Introduction

The aim of this study was to identify the plausibility of pathways for landscape development in the Green Heart. This chapter discusses the plausibility of the scenarios and the roadmap and adaptation pathway. In addition, the strengths and limitations of the research are discussed and directions for further research are proposed.

5.2. Plausibility of the scenarios

An important lesson for the peat meadows in the Green Heart is that the nature landscape scenario may not be feasible at all. A scenario with wet nature and a year-round high level, requires a precipitation surplus that may not be there due to climate change and influent seepage from the elevated peat-polder towards the polder. Active rewetting of the land requires water, and due to climate change this will be available in a very variable amount. Another important lesson of this study is that the involvement of landowners and land users, mostly farmers in peat meadows, is very important. They make the investment decisions that can spur or halt land use change, and they also have considerable knowledge about the area. The knowledge gap between government officials, planners and researchers on measures to prevent soil subsidence also increases if farmers are not involved in the thought process.

From the interviews, it clearly emerged that the Amstelscheg should be designed not only to prevent flooding, but also to combat drought. First of all, because a large area has been set up as a meadow bird reserve, which requires a high water level. Dry summers are becoming increasingly common in the Netherlands, and this could be dealt with adaptively. Besides nature, agriculture also depends on having sufficient water, and this can be threatened during prolonged periods of drought. The research of Samaniego et al. (2018) also shows this, as they mention that the European agricultural sector must adapt to periods with reduced soil water. This will require adaptive water management from Dutch water managers, as there will be less and less water available.

Another problem in the Amstelscheg is the increasing saline seepage. Due to soil subsidence and a rising sea level, the saline seepage continues to increase. Increasing saline seepage, as well as soil subsidence and climate change, is an irreversible trend that contributes to a situation in which current land use is finite. Measures against soil subsidence can help reduce the problem of saline seepage. However, additional measures may also be needed to combat salinization. For example, anti-salinization drainage is aimed at preventing salinization, while maintaining the drainage of the plot (van Meijeren et al., 2019).

The key indicators to assess the plausibility of the scenarios were used in a performance matrix (section 1.7.). It would not have made any difference for this study if weighting factors had been used, since the production landscape performed as well, or better as the nature landscape on all indicators. This indicates that the production landscape is preferred over the nature landscape scenario (Dodgson et al., 2009).

5.3. Adaptation pathway

The roadmap and adaptation pathway can partly be used for other peat meadows in the Green Heart, although unique local circumstances affect the scalability of these results. The reason behind this is that different people live in each area, different interest groups are active, a different province is responsible, a different RWA is in charge and different municipalities are involved. In addition, the physical environment also plays a role, for example the type of subsoil, land use and water management. Thereby, the Amstelscheg is a unique area in several respects: it is very close to

Amsterdam, the area crosses various administrative boundaries, leading to institutional splintering and it is a cultural-historical area. On the other hand, similar qualities of the Amstelscheg and other areas in the Green Heart are the living environment in the vicinity of the Randstad, the iconic landscape and the recreational areas. There will therefore also be many overarching interests involved.

In addition, defining tipping points proved to be a challenge for adaptation pathways in the context of soil subsidence. An adaptation tipping point is the point at which a certain action no longer meets the objectives of the plan, and a new action must then be implemented. Although soil subsidence, as well as sea level rise, is a gradually changing development, the exact timing of tipping points is difficult to determine. Particularly because it is difficult to determine, for example, at which point in time a dairy farm will no longer be possible. Not only the degree of drainage is important, but also the prices of feed, regulations on the number of days per year that cows are allowed to go outside and nitrogen regulations. These factors are uncertain, and therefore the adaptation pathway in this study is based on the soil subsidence rate, policy objectives of the RWA AGV and the Climate Agreement. Although defining tipping points proved challenging, the method is useful for identifying different measures, prioritizing them and planning them over time.

5.4. Strengths and limitations of the research

For this study, 9 semi-structured interviews were conducted to identify pathways for dealing with soil subsidence in peat meadows in the Amstelscheg. Although in theory this number of interviews could have been more, the key stakeholders were addressed. This was particularly evident in the interviews, when the interviewed stakeholders also referred to each other. On this basis, it can be stated that in the event of a repetition of this study, the results would in all likelihood be the same and therefore valid. Furthermore, with semi-structured interviews, there is always a risk that the researcher may influence the interviewees response (Abbott et al., 2010). This research has tried to limit this as much as possible by means of the phrasing of the questions in an open way.

5.5. Directions for further research

This study provides insight into the usefulness of the adaptation pathways approach in the context of soil subsidence due to peat oxidation, and contributes to the existing literature on soil subsidence and pathways in general. Besides, this study offers the most plausible adaptation pathway for the Green Heart as a recommendation for policymakers and other actors. In addition, the roadmap provides insights into which strategy could be followed to prepare peatland areas for a sustainable future. An elaboration of the costs and benefits would be a useful addition to make the adaptation pathways approach more robust.

After all, this study lacks the assessment of the costs of the various pathways. In the study by Van Hardeveld et al. (2018), a CBA was conducted on the spatial and temporal physical effects of three water management strategies. A CBA can provide insight into the balance between costs and benefits and can help in the decision-making process for measures. To develop a full picture of the plausibility of pathways in peat meadows, additional studies will be needed that examine the costs and benefits. This should include development and assessment of alternative business models for farmers, such as a shift in crops to paludiculture, a shift in cattle breed, or nature-inclusive agriculture. This is an important issue for future research as well.

6. Conclusion

In this study an answer was sought to the question: *What could be plausible pathways for addressing soil subsidence in peatland areas in the Green Heart?* Based on document analysis and interviews with key stakeholders, pre-defined pathways for the Amstelscheg were assessed.

The preferred pathway for the Amstelscheg is a future peatland area where the production landscape prevails. Agriculture in a much more extensive form, combining beef cattle that can withstand wet conditions, with submerged drainage, places where meadow birds can breed, and possibly places where paludiculture is practiced. Moreover, the results have shown that a step-by-step approach is preferable compared to a transformation overnight, and the adaptation pathway approach can be a valuable method in this respect.

The choice of measures to be introduced in the future, and when, will depend on, among other things, climate change developments, the annual rate of soil subsidence, political decisions and policy objectives. In addition, a party must take control in an administratively fragmented area such as the Amstelscheg. There is a lack of action, parties are waiting for society, and society is waiting for them. Foundation Beschermers Amstelland could take on the leading role, they are familiar with the actors, the roles they fulfil, and try to connect the organizations.

By restoring peat bog in vulnerable areas, a water buffer can be realized, because peat can retain a lot of rainwater. And drought control is an important factor for the future. Additionally, soil subsidence is reduced and fewer CO_2 equivalents are emitted. A step-by-step journey to a future-proof peat meadow landscape, using an adaptive approach, is the way forward.

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Appendix A: Pathways in practice

Adaptation pathways: Dynamic Adaptive Policy Pathways

Adaptive policy can help policymakers to design policies that are robust in the light of uncertainty. In adaptive policy, a long-term plan is drawn up. This plan indicates how it can adjust over time to various possible system changes. Benefits of adaptive policies are their ability to modulate responses to changes and their ability to coordinate actions in the short and long term (Raso et al., 2019). There are various approaches to develop adaptive policies: assumption-based planning (Dewar et al., 1993), real options (Hertzler, 2007; Jeuland & Whittington, 2014; Woodward et al., 2014), adaptive policy making (Hamarat et al., 2013; Walker et al., 2001), dynamic adaptive policy (Kwakkel et al., 2010), and dynamic adaptive policy pathways (Haasnoot et al., 2013). These approaches all use some type of signpost and trigger to identify when the policy needs to be changed.

The Dynamic Adaptive Policy Pathways (DAPP) approach was developed from the methods “Adaptive Policymaking” and “Adaptation Pathways” (Haasnoot et al., 2013). Some concepts used in these methods show resemblance; the concept of an adaptation tipping point is used in Adaptation Pathways and a trigger is used in Adaptive Policymaking. An adaptation tipping point is the point at which a certain action is no longer satisfactory to achieve the objectives of the plan. A new action must then be implemented. A trigger is the point that marks the required lead time for an action before a tipping point is reached. They are determined by how long it takes for a decision to be made and implemented (Haasnoot et al., 2013).

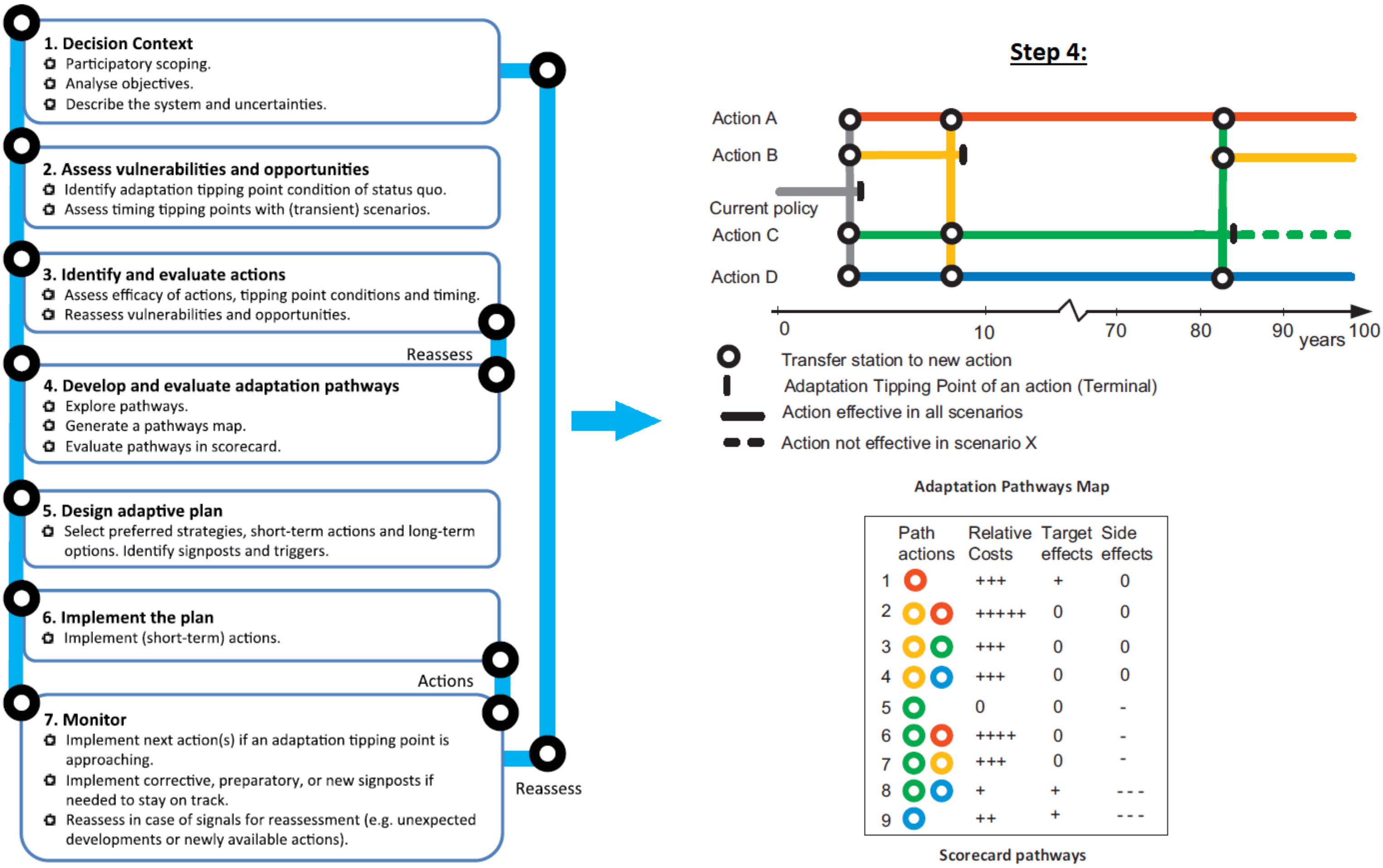

Figure A1: DAPP method in steps explained (Kwakkel et al., 2016) (left); An example of an Adaptation Pathways map and a scorecard presenting the costs and benefits of the 9 possible pathways (Haasnoot et al., 2013) (right).

In figure A1, the steps of the DAPP approach are shown. In step 4 of the method, a pathways map is created together with a scorecard. An example of such a map and scorecard can be seen on the right side of figure 4. In the map, starting from the current situation, an adaptation tipping point is reached after four years. Following the grey lines of the current plan, it becomes clear that there are four options. Both action A and D, should be able to achieve the targets for the next 100 years. If action B is chosen, a tipping point is reached within about five more years; a shift to action A, C or D is then needed to achieve the targets. If action C is chosen after the first four years, a shift to one of the other actions (A, B, or D) will be needed after approximately 85 years in the worst-case scenario (scenario X). In all other scenarios, the targets will be achieved for the next 100 years (dashed green line). The point at which the paths start to diverge can be considered as a decision point. Considering time for implementation of actions, these points lie before an adaptation tipping point.

Adaptation pathways: Subsidence canvas

Another approach which uses adaptation pathways and is used as a tool to cope with soil subsidence issues, is the 'subsidence canvas' (Ellen et al., 2018). It is based on a design approach, on the one hand it is about creating support among the actors involved and on the other hand about utilizing the creativity and resolving power of these actors (Van Buuren, 2017). Several steps are usually taken in the design approach. The first step involves clarifying and structuring the problem. After interpreting and defining what the problem is that needs to be addressed, it is important to identify the possible interventions with all the actors involved in a second step. In this step, the creativity and the present competencies of the actors involved is used as much as possible. Subsequently, in the next step, promising interventions are assessed for their effectiveness, feasibility and support, and work towards administrative agreements. Characteristic of the design approach is that every phase in the process goes into collaboration with the actors involved. The 'subsidence canvas' is shown in figure A2, the canvas was inspired by the Business Model Canvas (Osterwalder & Pigneur, 2010), but translated into the specific context of soil subsidence.

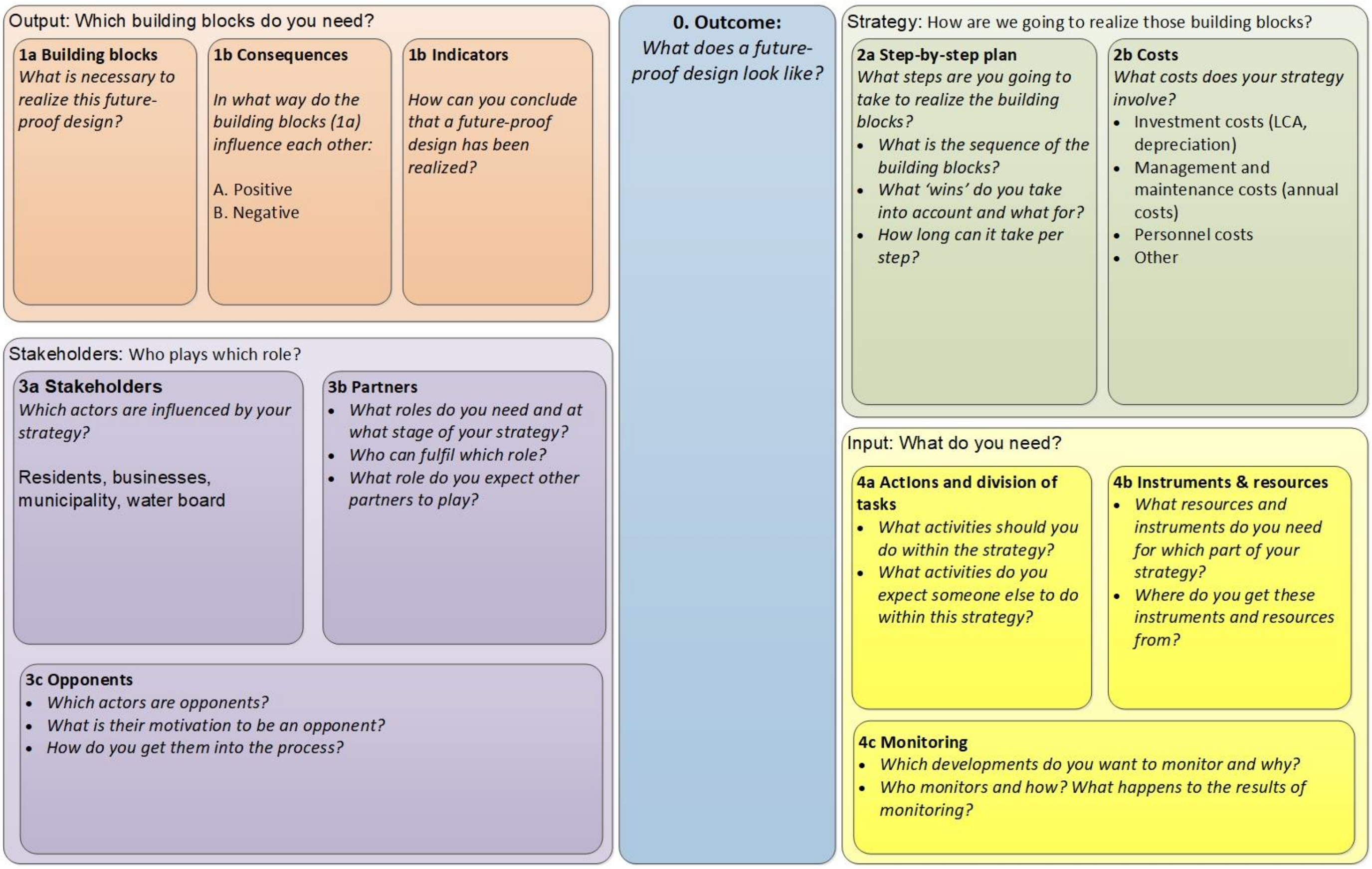

Figure A2: Subsidence canvas (Hommes, Ellen, Sardjoe, et al., 2018)

Transition pathways: Backcasting

Backcasting is an approach in which transition pathways are used. The approach is explicitly normative, by working backwards from a certain desirable future endpoint to the present in order to determine the physical feasibility of that future and what policy measures are needed to reach that point (Robinson, 1990). Backcasting is usually applied to complex long-term issues that involve many aspects of society, as well as technological innovations and change (Dreborg, 1996). Furthermore, other characteristics that favour backcasting are: a need for major changes, dominant trends are part of the problem and a time horizon which is long enough to allow a substantial space for an informed choice (Dreborg, 1996).

The backcasting approach is about encouraging the search for new development paths, since the conventional paths might lead to an undesired future. The emphasis is thus on the need for alternative solutions. When one or more scenarios have been identified that meet the objectives, it is time to analyse the consequences of the scenarios in different respects and the drivers that can influence their realization. This is also the first step of the analysis how the desired scenarios could be fulfilled (Höjer & Mattsson, 2000). The assumption of this approach is that after identifying the strategic objective in a certain future, it is possible to work backwards to determine which policies should be implemented to guide the area of interest in its transformation to that future (Quist & Vergragt, 2006).

The study conducted by Wallis & Ison (2011) analyzes key institutional and historical changes in water and natural resources management through the lens of transition theory in Victoria, Australia. Another study, by Müller et al. (2016) links a business model view to the concept of Sustainable Urban Water Management, for the process of transitioning to sustainability-focused water management. De Haan et al. (2016) present a modelling approach that show how transition pathways can emerge from a limited number of underlying change patterns. Both hypothetical cases, as a historical case are used to illustrate the approach. Lastly, the study conducted by De Haan & Rogers (2019) present the Multi-Pattern Approach, a framework for systematic analysis of transition pathways. A case study of water management in Melbourne is used to demonstrate the approach.

Appendix B: History & Scenarios for the Amstelscheg

History of the Amstelscheg

The Amstelscheg is an area in the Green Heart, between Amsterdam and Amstelveen. Around 4000 B.C. the ice caps had completely melted and the rise in sea level stopped. Behind a series of sand barriers, which formed the Dutch coast, a stretched peat marsh was formed. Peat consists of plant remnants that did not decompose completely because they ended up in the water and were not able to carry oxygen. The marsh became shallower and shallower and was eventually completely transferred into land (Abrahamse et al., 2012).

Peat acts like a sponge, it consists for about 80% of water. But the rainwater retained by the peat is much less nutrient-rich than the ground- and surface water. Only plants that need almost no nutrients, such as heather, cottongrass and peat moss, can survive there. In this nutrient-poor situation, peat moss emerged, with an even stronger sponge effect. In this way, the peat grows further up, creating a meters-thick pack of peat (Abrahamse et al., 2012).

Between 1000 and 1200, reclamation took place in the Amstelscheg. Around 1200, the landscape had a completely new structure, almost all the land was organized and used as agricultural land. In the late tenth or eleventh century the first farmers moved into the peat area (Abrahamse et al., 2012). The parcellation shape of the Rondehoep results from the course of the rivers and the simultaneous reclamation from the east and west sides. This ended at the 'meensloot', which runs through the middle of the Rondehoep and divides the area into approximately two equal parts (Abrahamse et al., 2012).

Reference scenario

Figure B1: Visualization of the reference scenario (Stedenbouw & Landscapes, 2019).

Soil subsidence

Soil subsidence causes high social costs. If the current policy is continued, the annual costs due to soil subsidence for the peat meadow area of Amstel Gooi en Vecht (AGV) are estimated as follows:

AGV (costs of sluices/pumping stations, water management, costs of sludge removal, costs of dikes, shortage of water storage)	€37,773 million
Sewage, dikes, roads	€22,143 million
Housing	€3,177 million

By comparison, AGV's annual operating costs are approximately €180 million.

Nationally, the PBL has calculated that the costs of subsidence in the peat meadow area can reach up to € 22 billion in 2050, these costs mainly consist of mitigation and repair costs of damage caused (den Born et al., 2016).

Water requirement
Approximately 5 million m^3 of water is introduced into the Rondehoep every year (Amesz, 2017). There are approximately 25 inlets from the Waver and the Amstel. The inlet is almost twice as much as the annual precipitation surplus (in an average year). Approximately 1.65 million m^3 of water is let into the Bovenkerkerpolder every year, mainly to change the urban water after sewer overflows (van Zon, 2017). Also, in polders with brackish seepage, water is often let in for flushing.

On the east side of the Rondehoep, excess water is pumped via a pumping station to the Waver. The pumping station has a capacity of 104 m^3/min. Data on the annual discharge have not been found, but the estimate based on the known water balance elements is that it amounts to approximately 6 million m^3. From the Bovenkerkerpolder, including the urban area, approximately 7.9 million m^3 of water is deposited in the storage basin every year (van Zon, 2017).

Water quality
The ecological water quality in the Ouderkerkerplas and the Amstellandboezem is "inadequate" and "poor" in the canals of the Bovenkerkerpolder, Middelpolder and the Rondehoep (Waterschap AGV, 2020). The table below (B1) shows the biological and chemical factors on which this water quality is based.

This legend applies to the table below:

	Biology and general physical chemistry	**Contaminants**
	Very good	Satisfies
	Good	-
	Mediocre	-
	Inadequate	-
	Poor	Does not suffice

Table B1: Water quality data 2019, AGV

Polder	**Biology**				**Physical chemistry**				
	Macrofauna	Other water flora	Fish	Phytoplankton	Nitrogen	Phosphorus	Salinity	Transparency	Temp.
Amstellandboezem									
Rondehoep									
Ouderkerkerplas									
Bovenkerkerpolder									
Middelpolder									

The goal for 2027 is that the ecological water quality in all the above waters should be good. AGV hopes to achieve this, among other things, by cooperating with the agricultural sector and thereby reducing the leaching of manure and plant protection products. To improve the situation in the Bovenkerkerpolder, the polder pumping station will be modernized this year. This makes it possible to better maintain the established water levels and thereby reduce the need for flushing. This improves the conditions and living conditions for the development of aquatic plants. The new management must also lead to less damage and/or mortality to the fish population present.

Biodiversity
The meadow birds in the Rondehoep are the showpiece of the Amstelscheg. Landschap Noord-Holland, together with the farmers, manages a reserve of 180 ha. A large part of the reserve is hay meadow and is only mowed after June 8 or 15. The water level in the reserve is kept high, to create an optimal foraging and breeding area for the meadow birds. Where meadow birds are declining strongly nationally, the numbers in the Rondehoep are at the same level as 25 years ago, with, for example, 225 pairs of godwits and 60 pairs of skylarks. The meadow birds are not limited to the reserve. Plenty of meadow birds also breed on the agricultural plots in the Rondehoep and beyond. Many farmers take measures for meadow bird protection.

Nature values also emerge outside the meadow bird areas. Every year thousands of wigeons, shovelers and gadwells hibernate on the Ouderkerkerplas. Species-rich marsh vegetations grow along the banks. The forests and parks in the city edges and the small landscape elements add extra variety, making Amstelland a habitat for grass snakes, weasels, ermines, polecats, rabbits, frogs, toads, salamanders, voles and birds of prey, such as kestrel, buzzard and hawk. No data have been found on the precise distribution and development of these species, including insects such as butterflies and bees. As elsewhere, urban pressure and intensification of agriculture will certainly pose a threat. Water quality is another concern.

Landscape
The experience of the landscape is strongly determined by the storage basins and the open meadows. Historical farms, waterworks and ditch patterns ensure that the draining history is still clearly legible. The contrast with the younger urban edges and infra-structural intersections is big. The storage basins form attractive, but often busy, city-country connections. The Amstel continues into the center of the city and here are several country estates and recreation farms. The peat meadow areas are only internally accessible and largely inaccessible to cyclists and hikers. It is expected that this will remain the case with unchanged policies in the future.

Greenhouse gas emissions
Within the Amstelscheg is approximately 3,500 ha of peat area, of which approximately 250 ha of meadow bird reserve. Based on the emissions from comparable peat areas, this produces an annual emission of 54,000 tons of CO_2 equivalents (0.05 Mton).

Dairy farming itself is also a source of greenhouse gases. The production of 1 kg of milk produces an average emission of 1.4 kg of CO_2 equivalents (van Capellen, 2014). The exact emissions strongly depend on the business operations and the local circumstances. Assuming 40 dairy farms and an average milk production of 530,000 kg (Westerink et al., 2016), the annual emissions are approximately 30,000 tons of CO_2 equivalents in the Amstelscheg.

The total emission of the land use is therefore approximately 84,000 tons of CO_2 per year. This is in line with what a mature Dutch forest of more than 19,000 ha records each year: an area more than four times as much big as the whole Amstelscheg (Schelhaas et al., 2017).

Production landscape scenario

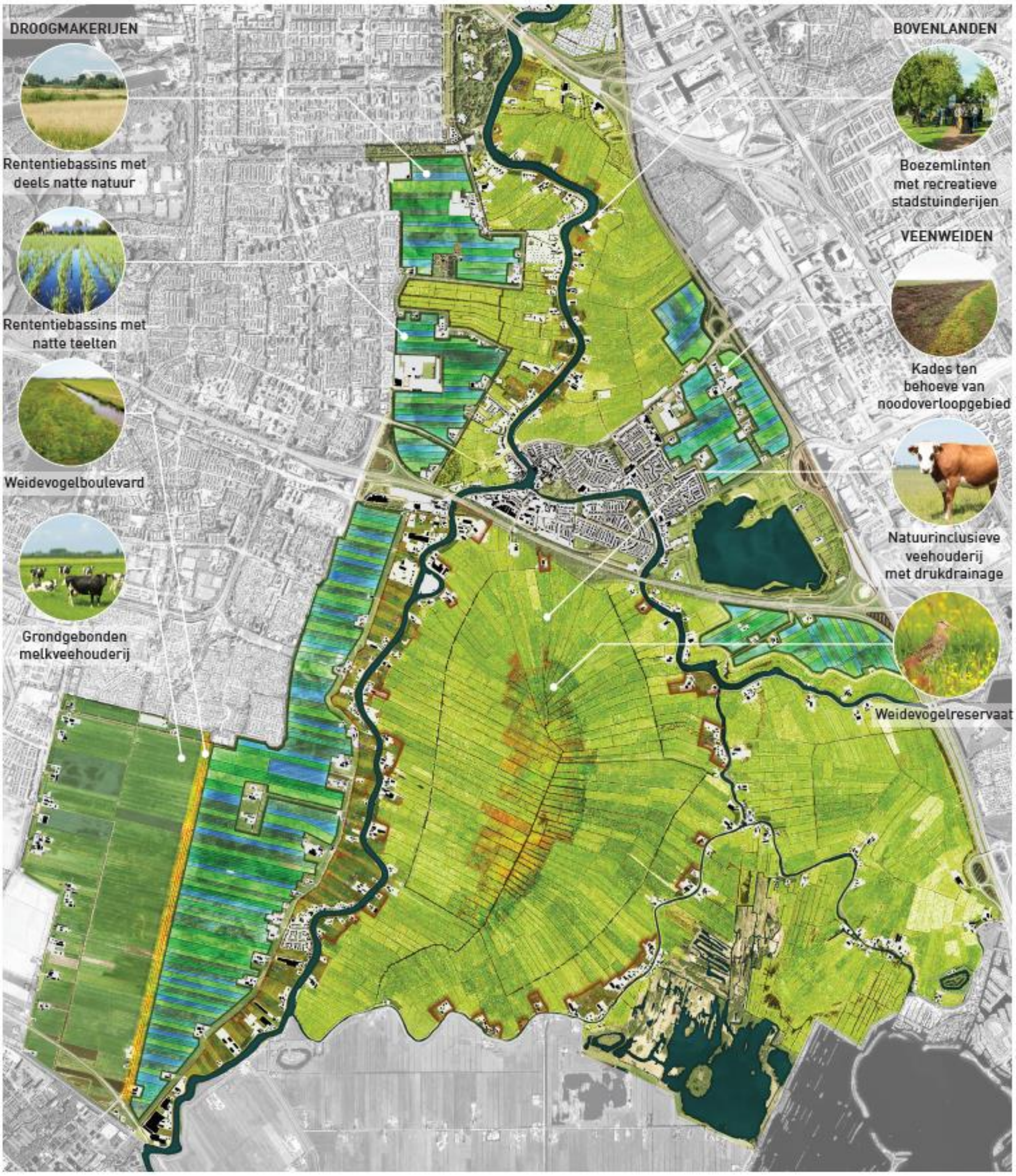

Figure B2: Visualization of the production landscape scenario (Stedenbouw & Landscapes, 2019).

In this scenario, it is assumed that the current land use will be maintained for food production. Current dairy farming will develop in the direction of “circular agrofood systems”. This can be achieved according to these three principles:

1. Focus on vegetable production for human consumption;
2. Return residual flows from the food system to the food system as much as possible;
3. Using animals for what they are good at: converting crops and residual flows that are inedible to humans into edible products (dairy products, eggs, meat).

Besides, food production will focus more on the nearby urban sales market in Amsterdam. The own dairy brand (Amstel dairy) is already a good example of this trend.

Measures

Stakeholder	Measure
RWA	• Water level increase • Water level fluctuation • Construction of water retention basins in the polder
Farmer	• Construction of submerged drains in agricultural peat area • Changing from business model to nature-inclusive agriculture • Changing from business model to paludiculture

To limit soil subsidence in the agricultural peat area in the Amstelscheg, the primary focus is on submerged drains, which is underground irrigation of the peat soil. The starting point is that the groundwater level in the plots is a maximum of 30 cm below ground level in the summer. Because the groundwater level in the plots is regulated by the submerged drains, increased level fluctuations in the ditches are possible without limiting agricultural uses. With a maximum ditch fluctuation of 60 cm, a lot of extra storage is created, and both the inlet and the peak discharges can be limited.

The meadow bird reserve maintains its current water level management, marshland in the winter and the lowest level permitted in summer is 40 cm.

Research has shown that the use of submerged drainage leads to an increase in the intake requirement by 10 to 15%. The proposed fluctuation in water level will contribute substantially to this but will not be sufficient to maintain the ditches in dry summers. Additional retention facilities are required for this. It is proposed to establish a zone of retention basins adjacent to the peat areas in the polder. This means: open water with approximately 1 m level fluctuation. The water depth can vary depending on the use. Water is pumped up from these retention basins to the peat areas. Moreover, because the retention areas are projected on soils with residual peat, the degradation of this peat and thus the emission of greenhouse gases is limited. In the other parts of the polder with predominantly clay soil, less restrictions apply to agricultural land use from soil and water. Land-based dairy farming remains possible here. However, there are limits to further lowering the water level because of the risk of soil cracking and salinization.

Land use

Dairy farming remains possible in the drainage zone, but because on average the groundwater level rises, grass production and accessibility decrease. This requires an extensification of agricultural land use: lower livestock density and mowing at a later moment in the year. The emphasis will be less on milk production for the world market, and more on local quality products for the regional market. This can be combined well with additional agricultural nature management. It is expected that the necessary investments for the construction of submerged drains (approximately €5,000 per ha) cannot be fully recouped. Therefore, government co-financing is needed.

The retention basins in the polders are the most profound change in the landscape. By using these for 'paludiculture', they gain an additional production function and economic value. Floating crops such as duckweed and algae can be combined well with the fluctuations in water levels, but cultivation such as bulrush can also withstand fluctuating water levels. The retention facilities can be constructed in phases, adding new water compartments step-by-step.

Land-based agriculture remains possible in the other parts of the polder. Larger stables can be accommodated on the relatively resilient clay soil. However, the principles of a circular agrofood system will have to be met in the long term. This can be done by, for example, using extra animal feed from the adjacent paludiculture. Azolla is very suitable for this.

Effects on soil subsidence

In this scenario, the starting point is that the groundwater level will not drop further than approximately 30 cm below ground level due to the use of submerged drains in the summer. Because the top 30 cm still oxidizes, soil subsidence will not be completely stopped. In the Rondehoep, the drop in 2100 will not be 1 m, but 40 to 50 cm. The water level will therefore have to be lowered periodically, and this also applies to the location of the drains.

Soil subsidence is expected to be of the same order of magnitude in the meadow bird reserve. No submerged drains are used here, but because the water level in winter and in spring is at ground level, the groundwater will only reach its lowest level at the end of the summer and the total oxidation period will be shorter.

Effects on water drainage

The level fluctuations in the ditches and in the retention basins also make it possible to cap large discharge peaks and prevent waterlogging in the storage basin. It is important here that in normal situations a certain reserve capacity remains in the water system. This is easy to arrange with targeted water level management.

Effects on biodiversity

The meadow birds are given additional opportunities in this scenario, and nature-inclusive agriculture will also increase the natural value of ditches and banks. Because the Netherlands has an international responsibility for the conservation of meadow birds, in particular the godwit, this is an important plus. Paludiculture may have an additional significance for water and marsh species, but that depends very much on the precise cultivation.

Effects on landscape

The biggest asset of this scenario is that the open Dutch polder landscape will be maintained. Even with cows in the pasture, although these will be other cows than the high-yielding Holstein dairy cows, but rather "dual-purpose cows" such as the Blaarkop. Nevertheless, there are also major changes: the retention basins with paludiculture form an entirely new landscape type.

Business model

Waternet's research shows that due to the implementation of submerged drainage, farmers have slightly higher profits each year compared to current policy (Pelsma et al., 2020). Substantial investments will, however, be required to construct a submerged drain.

In addition, in this scenario, part of the land-based dairy farming is lost due to the retention basins. There is room for wet paludiculture here, which is currently being researched extensively. AGV is committed to researching these alternative revenue models for wet crops (Waternet, 2019).

Nature landscape scenario

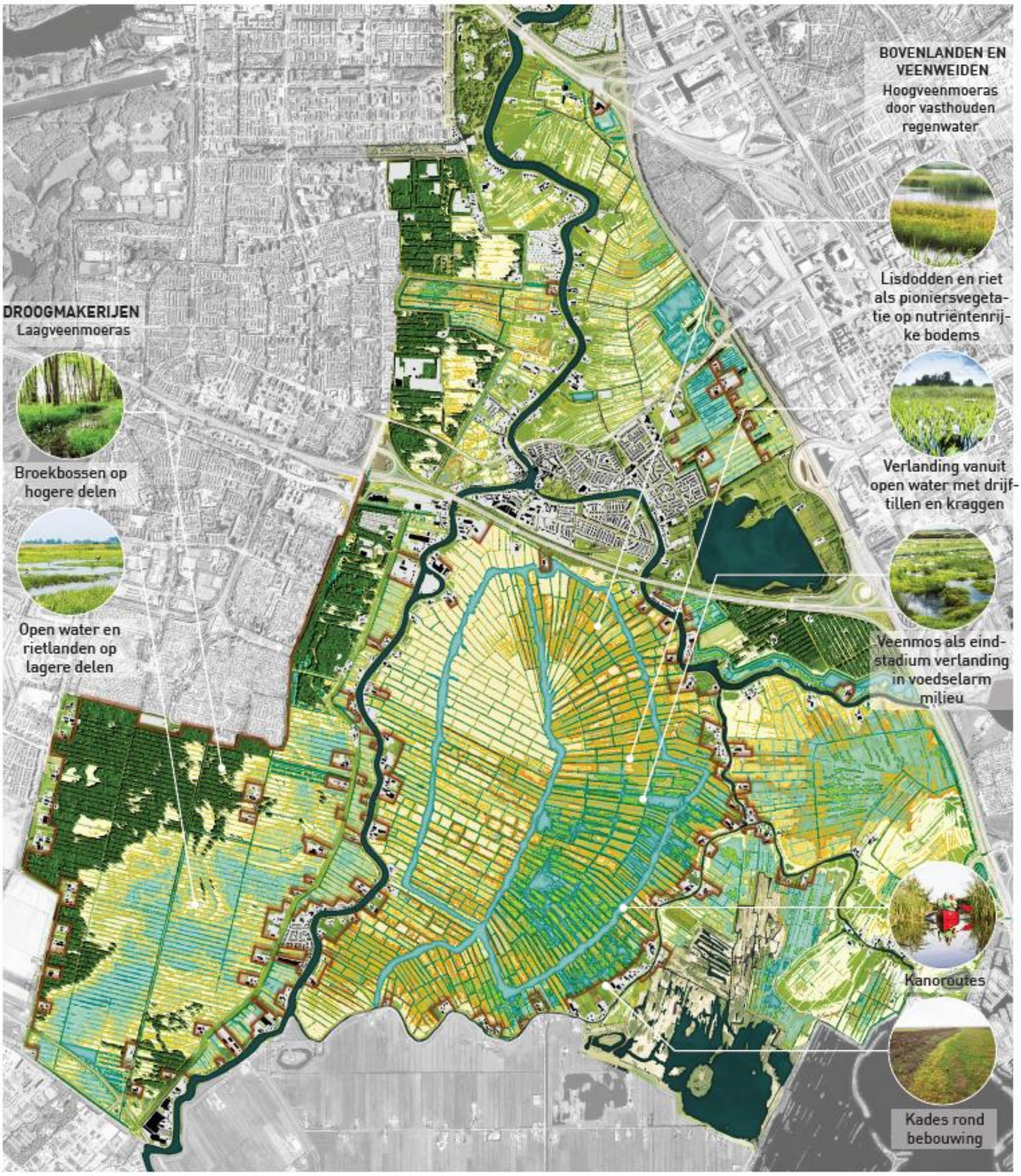

Figure B3: Visualization of the nature landscape scenario (Stedenbouw & Landscapes, 2019).

Measures

Stakeholder	Measure
RWA	• Active rewetting of peat • Maximum retention of rainwater • Change of business model
Farmer	• Change of business model

The core of this scenario is active rewetting of peat and maximum retention of rainwater. The Rondehoep is particularly suitable for this, due to the large contiguous surface area, the cup-shaped location and the lack of buildings and roads in the center. The buildings along the edges already have their own water level management ("high water supply") and are protected against flooding from the center by high water quays. These high water quays are already being constructed in the context of the designation of the Rondehoep as an emergency overflow area, but will have a different function in this scenario, namely to enable peat formation. By retaining more rainwater in the Rondehoep and elsewhere, and allowing inundations, the need for a separate emergency overflow area will disappear (in the long term).

Because there is a net precipitation surplus (of approximately 250 mm) in the Netherlands on an annual basis, the Rondehoep can gradually be flooded in several years if the rainwater is no longer drained. Due to the road side there is still some water loss, but this is less than the precipitation surplus. In addition, the road side is limited by the wetting of the adjacent polders. In this scenario, inlet water is no longer needed from the rivers.

The polders form the original raised bog domes. Now they are deep wells in the water system, which draw water from the adjacent peat areas and locally extract even brackish water from the deeper subsoil, which in turn leads to an additional need for water flushing. From the point of view of sustainable water management, raising the water level is a sensible option. This is also easy to realize due to the seepage present. In this scenario, reclaimed soil with residual peat on the surface and/or with brackish seepage is raised and transformed into nature. The level of elevation can vary from puddle to deeper water, depending on the water and nature goals. An option is to gradually increase the level and allow it to grow along with the peat formation.

Land use

This model requires a large-scale transformation of agricultural land into a nature reserve. Peat restoration will increase biodiversity and landscape diversity. Peat bogs are internationally valuable and very characteristic of the Dutch delta. Peat restoration can yield iconic landscape images, which are not inferior to the well-known image of cows in the pasture.

For the Rondehoep, the aim is to restore the original raised bog dome, while retaining the open character and the cultural-historical ditch pattern. The prevention of forest development is one of the points of attention. Further research and practical tests must show how this process can best be controlled. Some ditches are kept open for water management and recreation. Other ditches may gradually close but will remain visible in the landscape for a long time due to deviating vegetation.

In the uplands along the storage basins, often with a clay deck, the development of reed and forest will occur. This fits in with the natural gradient of the peat area and increases the ecological and landscape diversity. The uplands form green borders around the open raised bog centers, within which new recreational facilities can be perfectly integrated.

In the polders, especially nutrient-rich (clay) marshes are expected in the first stage, which in ecological terms have a clear added value compared to the nutrient-poor raised bog centers, for example as a foraging area for birds. Depending on the water strategy and management, completely rainwater-dependent, nutrient-poor swamp may eventually emerge.

Effects on water drainage
It is feared that areas with a lot of open water will quickly lead to flooding, because rainwater cannot be stored in the soil. However, this assumes that the water is kept at a fixed level and that every cm of water level rise is directly drained away. This is not the case in this scenario. Natural water level fluctuations are possible and desirable, within certain limits. This results in a large storage capacity and helps to prevent flooding. Due to sufficient 'excess height' at the edges and targeted water level management, discharge peaks can easily be capped. The sponge function of the peat does the rest. If this is applied on a larger scale in the Green Heart, the storage basin can be relieved structurally and the need to construct separate 'emergency spillways' will be reduced. This still requires further investigation.

Effects on biodiversity
The meadow birds will have to share their place in this scenario with other species of wetland peatlands and will probably occur in lower densities. In any case, the diversity of species will increase enormously. Nutrient-poor raised peat bog cores, for example, can contain rare species of dragonflies and butterflies. The more nutrient-rich edges and the low-lying marshland, form habitat for all kinds of water and marsh birds. Internationally, raised peat bogs and low-lying marshland are particularly valuable and originally very characteristic of the Dutch delta.

Effects on landscape
The fear that the Amstelscheg will automatically grow into forest in this nature scenario is unjustified. With a targeted wetting strategy and good transition management, openness can be maintained. In the longer term, little or no management is needed in the peat bog areas: due to the wet and nutrient-poor conditions they will naturally remain tree-free. The character of the landscape will certainly change considerably. The ditches will partially close, reed beds and swamp forests may develop locally. There will be no more cows in the meadows, at most 'big grazers' on the drier parts. Opinions differ as to whether this is bad. In any case, the interconnected 'robust' nature areas in this scenario offer new opportunities for nature experience and recreation. In contrast to vulnerable meadow bird areas, a more diffused network of recreational access with cycle paths, footpaths and canoe routes is possible.

Business model
The transformation from agriculture to nature and recreation is causing a huge turnaround in the area. This scenario focuses entirely on halting subsidence and reducing CO_2 emissions. The business model for farmers seems to be completely gone in this scenario, as agriculture no longer occurs. This raises questions: What role is there for farmers?; How much will it cost to buy them out, and is that even possible?.

The profit of the nature landscape scenario is in the CO_2 reduction. If a system of "carbon credits" is introduced, the economic efficiency can be higher than that of the production landscape scenario. But also, here considerable investments are needed to convert 3000 ha of agricultural land into nature.

Appendix C: Stakeholder Analysis

According to literature, the following steps are usually distinguished in a stakeholder analysis (Grimble, 1998; Runhaar et al., 2006):

1. Definition of the policy problem
2. Identification of actors involved in the subject
3. Identification of formal tasks, competences, interests, goals and problem perceptions of the actors involved

Step 1: Definition of the policy problem

Step 1, the definition of the policy problem, has been discussed extensively in previous chapters. Soil subsidence is becoming an increasingly serious problem, especially in view of climate change, and is causing high costs. In the Green Heart region, the most common cause is groundwater lowering for enabling agriculture. The process of peat oxidation, causing the soil to subside, will not stop without interventions. That is why this research aims to assess new scenarios and implementation routes for a future-proof peat meadow area in the Amstelscheg.

Step 2: Identification of actors involved in the subject

For this step, the methodology of Ballejos & Montagna (2008) is used. The steps they used are visualized in figure D1.

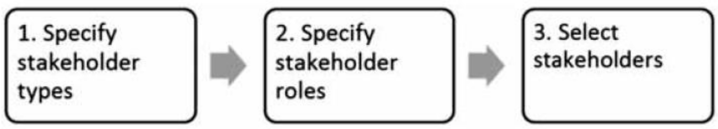

Figure D1: Stages of stakeholder identification (Ballejos & Montagna, 2008)

First, all potential stakeholder types need to be identified. According to Ballejos & Montagna (2008), four criteria are used for identifying stakeholders: 1) functional; 2) geographical criterion; 3) knowledge and abilities; and 4) hierarchical level. In addition, André et al. (2012) propose to divide stakeholders among the scope of their activities. Table D1 presents an overview of the stakeholders per selection criteria and scope of activities.

Table D1: Stakeholder identification table

Selection criteria	Scope: Local	Scope: Regional	Scope: National/global
Functional: - those who can affect change - those affected by response - those who represent the interest of their community	• Municipalities • Companies • Citizens • Local political parties	• Province	• Sectoral authorities • Political parties
Geographical location - those operating/living/working in the region	• Municipalities • Property owners • Local business • Private companies	• Regional water authority (RWA)	• RWA

Knowledge and abilities: Stakeholders with certain knowledge and skills related to soil subsidence, adaptation, regional knowledge	• Citizens • Consultants	• Universities • RWA	• Universities • Research institutes
Hierarchical level: Decision-makers and other influential stakeholders who indirectly could facilitate or hinder adaptation	• Municipalities • Individuals	• Decision-makers	• Dutch government • EU

Subsequently, the stakeholder roles can be further specified. The roles specified in table D2 are generic and derived from literature (André et al., 2012; Ballejos & Montagna, 2008; Ebi et al., 2004). The letters in the third column refer to the four criteria in table D1. Table D2 is used as a discussion tool and a checklist that complements table 1 (André et al., 2012).

Table D2: Stakeholder roles

Stakeholder role	Example/definition	Criteria
Supporters	Stakeholders who prepare and support adaptation through advice and guidance, evaluation of adaptation etc.	F
Providers	Stakeholders who provide research, knowledge and information on soil subsidence causes, impacts, vulnerabilities and adaptation etc.	K
Disseminators	Those who disseminate soil subsidence knowledge and information	K
Funders/sponsors	Funders of adaptation measures and/or soil subsidence related research	F
Experts	Local experts on specific local conditions, water management experts on soil subsidence and practical and technical solutions	F/K/G/H
Implementers	Stakeholders responsible for implementing adaptation measures	F
Coordinators	Stakeholders that coordinate other actors, research or adaptation strategies in general	F/K
Responsible and/or decision-makers	Stakeholders that have an explicit responsibility for water management and soil subsidence	F/H
Regulators	Initiators or implementers of new legislations, as well as changes in norms and standards	F/H
Affected	Stakeholders exposed and/or vulnerable to soil subsidence	G/K

The last step of identification of stakeholders involved in the subject is the selection of stakeholders. This will show who is dealing with soil subsidence in the Amstelscheg and who should be interviewed for this study. The selection is based on a comprehensive scan of official documents such as local and regional planning documents and reports about the Amstelscheg (Ellen et al., 2018; Jeuken & Reeder, 2011; landschapsarchitectuur en Stedenbouw & Landscapes, 2019; Westerink et al., 2016). Besides, table D1 and D2 were used in this selection process. Table D3 gives an overview of the selected stakeholders.

Table D3: Selected stakeholders

Stakeholder role	Selected stakeholders
Supporters	Municipality of Ouder-Amstel Municipality of Amsterdam Municipality of Amstelveen Province of North-Holland Netherlands Agricultural and Horticultural Association (LTO) Landschap Noord-Holland (LNH) Beschermers Amstelland Wij.land Stichting Duurzaam Agrarisch Natuurbeheer (DAN) Agrarisch Collectief Noord-Holland Zuid
Providers	Waternet RWA Amstel, Gooi and Vecht Wageningen University Utrecht University Deltares Peat meadow Innovation Centre Foundation for Applied Water Research (STOWA) The Netherlands Environmental Assessment Agency (PBL)
Disseminators	Deltares Wageningen University
Funders/sponsors	Province of North-Holland RWA Amstel, Gooi and Vecht Waternet
Experts	Mark Kuiper (Local expert) Gilles Erkens (Deltares) Frank Lenssinck (Peat meadow Innovation Centre) Henk van Hardeveld (Waternet)
Implementers	Province of North-Holland Municipality of Ouder-Amstel Municipality of Amsterdam Municipality of Amstelveen Farmers (Boeren van Amstel) Wij.land
Coordinators	Province of North-Holland RWA Amstel, Gooi and Vecht
Responsible and/or decision-makers	RWA Amstel, Gooi and Vecht

Regulators	Dutch government EU
Affected	Property owners Farmers Local businesses Private companies

<u>Step 3: Identification of formal tasks, competences, interests, goals and problem perceptions of the actors involved</u>

Step 3 involves identification of the tasks, competences, interests, goals and problem perceptions of the stakeholders. This was conducted for the stakeholders who were interviewed. The results are shown in table D4.

Table D4: Stakeholders and their formal tasks, competences, interests, goals and problem perceptions

Stakeholder	Formal tasks & competences	Interests & goals	Problem perceptions
Municipality	• Makes zoning plans. It states which area is intended for houses, which part for nature and which part for companies. • Municipalities are responsible for groundwater in urban areas. The municipality also ensures the discharge of waste water and excess rainwater through the sewer system. This is stated in the Water Act and the Environmental Management Act.	• Citizens	• Budget constraints
Province of North-Holland	• Supervises the RWA ▪ Groundwater levels (GGOR): Before the GGOR is established, an assessment takes place in consultation between the regional and local authorities (provinces, municipalities and RWA). When the province approves the GGOR after this assessment process, the RWA has an obligation to make efforts to implement the water management adjustments. • Supervises municipalities • Supervises compliance with environmental laws for air, soil and water • Determines where roads, railways, shipping connections, industrial areas, agricultural and nature	• Sustainable spatial development & water management • Environment, energy & climate • Vital countryside, nature management & nature reserve development • Regional accessibility & regional public transport • Cultural infrastructure & preservation of monuments	• Budget constraints • EU policy • Climate targets must be met, the emission of CO_2 equivalents from peatland must be reduced.

	reserves and recreational facilities will be located • Realizes new nature and preserves current nature		
Netherlands Agricultural and Horticultural Association (LTO)	Represents more than 35,000 agricultural entrepreneurs and is committed to their economic and social position.	• Farmers	• Legislation for farmers
Landschap Noord-Holland (LNH)	Their advisors help municipalities, RWAs and other organizations to realize various projects. From ecological research and green management to complete design plans.	• Increasing biodiversity • Making the landscape climate proof	• Nature is deteriorating • Nitrogen problems • Biodiversity is decreasing
Beschermers Amstelland	Stands for the preservation of the Amstelscheg as an open and accessible, vital agricultural area with great natural values in which people can farm and recreate with respect for the landscape, nature and cultural history.	• Landscape conservation • Residents in the area	• Urbanization pressure • Fragmentation of the landscape
Waternet	Waternet works on behalf of the RWA Amstel, Gooi en Vecht and the Municipality of Amsterdam. They are the only water company in the Netherlands that takes care of the entire water cycle. • Ensure strong dikes. • Ensure that the water in polders and in nature is at the correct height. And that it can flow well. • Measure the groundwater levels. • Keep the canals clean.	• They operate on what stakeholders want. They are not a steering party, but act on what democracy decides.	• Water management costs
Farmers (Boeren van Amstel)	• Milking and taking care of cows • Work the land • Administrative work	• Business • Animal welfare	• Difficult to make enough money • A lot is said and written about farmers, involvement is often lacking.

Appendix D: Calculations of drainage depth until 2100

The following formula was used (De Lange & Gunnink, 2011):

$\Delta z = d_{dry} * (1 - e^{(-V_{ox} * \Delta t)})$

$\Delta z = subsidence\ due\ to\ peat\ oxidation\ [m]$

$d_{dry} = thickness\ of\ peat\ above\ groundwater\ level\ [m]$

$V_{ox} = oxidation\ rate$

$\Delta t = oxidation\ time\ [y]$

Assumptions:

- Soil subsidence is 1 centimeter/year
- Drainage depth of 60 centimeter in 2020 (Stedenbouw & Landscapes, 2019)
- The calculated oxidation rate becomes $0{,}0168075\ y^{-1}$
- RWA AGV: follows soil subsidence 75% between 2030 – 2040
- RWA AGV: follow soil subsidence 50% between 2040 – 2050
- RWA AGV: follows soil subsidence 10% from 2050 onwards. This is based on the fact that CO_2 emissions must be reduced by 90% by 2050, so it is assumed that soil subsidence must be reduced by 90% accordingly (*Klimaatakkoord*, 2019).

Column A: $Year$

Column B: $(Initial\ drainage\ depth_y) - (Initial\ drainage\ depth_y * (1 - e^{(-0{,}0168075 * 1)})$

Column C: AGV policy 75%, 50%, 10%

Column D: $(Remaining\ drainage\ depth_{y-1} - Initial\ drainage\ depth_y) * (100\% - AGV\ policy_y)$

Column E: $Initial\ drainage\ depth_{y-1} - Drainage\ including\ policy_y$

Column F: $Remaining\ drainage\ depth_y * 100$

Column A	Column B	Column C	Column D	Column E	Column F
Year	Initial drainage depth [m]	AGV policy [%]	Drainage including policy	Remaining drainage depth [m]	Remaining drainage depth [cm]
2020	0,6	75%	-	0,6	60
2021	0,589999775	75%	0,002500056	0,597499944	59,74999437
2022	0,580166224	75%	0,00433343	0,585666345	58,56663448
2023	0,570496569	75%	0,003792444	0,57637378	57,63737798
2024	0,560988079	75%	0,003846425	0,566650144	56,66501437
2025	0,551638067	75%	0,003753019	0,557235059	55,72350595
2026	0,542443892	75%	0,003697792	0,547940275	54,7940275
2027	0,533402957	75%	0,00363433	0,538809562	53,88095625
2028	0,524512707	75%	0,003574214	0,529828743	52,98287431
2029	0,515770632	75%	0,003514528	0,52099818	52,09981797
2030	0,507174261	50%	0,006911959	0,508858673	50,88586729
2031	0,498721167	50%	0,005068753	0,502105508	50,21055082
2032	0,49040896	50%	0,005848274	0,492872893	49,28728925
2033	0,482235293	50%	0,0053188	0,48509016	48,50901603
2034	0,474197857	50%	0,005446151	0,476789142	47,67891418
2035	0,466294382	50%	0,00524738	0,468950477	46,89504774
2036	0,458522634	50%	0,005213922	0,46108046	46,108046
2037	0,450880418	50%	0,005100021	0,453422613	45,34226126
2038	0,443365575	50%	0,005028519	0,445851899	44,58518989

2039	0,435975982	50%	0,004937958	0,438427617	43,84276166
2040	0,428709552	10%	0,008746258	0,427229724	42,72297243
2041	0,421564232	10%	0,005098943	0,423610609	42,36106092
2042	0,414538003	10%	0,008165345	0,413398887	41,33988868
2043	0,407628881	10%	0,005193005	0,409344998	40,93449982
2044	0,400834913	10%	0,007659076	0,399969805	39,99698048
2045	0,394154181	10%	0,005234061	0,395600852	39,56008521
2046	0,387584797	10%	0,00721445	0,386939731	38,69397313
2047	0,381124905	10%	0,005233344	0,382351453	38,23514528
2048	0,37477268	10%	0,006820896	0,374304009	37,43040091
2049	0,368526328	10%	0,005199913	0,369572767	36,95727669
2050	0,362384084	10%	0,006469814	0,362056513	36,20565134
2051	0,356344213	10%	0,00514107	0,357243014	35,72430141
2052	0,350405009	10%	0,006154204	0,350190009	35,01900092
2053	0,344564794	10%	0,005062693	0,345342316	34,53423161
2054	0,338821919	10%	0,005868358	0,338696437	33,86964366
2055	0,333174759	10%	0,004969509	0,333852409	33,3852409
2056	0,327621722	10%	0,005607619	0,327567141	32,75671407
2057	0,322161237	10%	0,004865314	0,322756408	32,2756408
2058	0,316791762	10%	0,005368182	0,316793055	31,67930551
2059	0,31151178	10%	0,004753147	0,312038614	31,20386144
2060	0,3063198	10%	0,005146933	0,306364848	30,63648475
2061	0,301214355	10%	0,004635443	0,301684357	30,16843573
2062	0,296194003	10%	0,004941319	0,296273036	29,62730364
2063	0,291257325	10%	0,00451414	0,291679863	29,16798628
2064	0,286402927	10%	0,004749242	0,286508083	28,65080829
2065	0,281629437	10%	0,004390781	0,282012146	28,20121461
2066	0,276935508	10%	0,004568975	0,277060463	27,70604629
2067	0,272319812	10%	0,004266586	0,272668922	27,2668922
2068	0,267781046	10%	0,004399088	0,267920724	26,79207239
2069	0,263317928	10%	0,004142516	0,26363853	26,36385303
2070	0,258929197	10%	0,0042384	0,259079529	25,90795288
2071	0,254613614	10%	0,004019324	0,254909874	25,49098737
2072	0,250369958	10%	0,004085924	0,250527689	25,05276892
2073	0,246197031	10%	0,003897592	0,246472366	24,64723656
2074	0,242093655	10%	0,00394084	0,242256192	24,22561917
2075	0,23805867	10%	0,00377777	0,238315885	23,83158853
2076	0,234090936	10%	0,003802454	0,234256215	23,42562154
2077	0,230189333	10%	0,003660195	0,230430741	23,04307414
2078	0,226352757	10%	0,003670186	0,226519147	22,65191468
2079	0,222580126	10%	0,003545118	0,222807639	22,28076388
2080	0,218870374	10%	0,003543538	0,219036588	21,9036588
2081	0,215222452	10%	0,003432722	0,215437652	21,54376519
2082	0,211635331	10%	0,003422089	0,211800363	21,18003632
2083	0,208107996	10%	0,003323131	0,2083122	20,83121999
2084	0,204639451	10%	0,003305474	0,204802522	20,48025217
2085	0,201228717	10%	0,003216425	0,201423027	20,14230265
2086	0,197874829	10%	0,003193378	0,198035339	19,80353392
2087	0,194576841	10%	0,003112648	0,194762181	19,4762181

2088	0,191333821	10%	0,003085524	0,191491317	19,14913169
2089	0,188144852	10%	0,003011818	0,188322002	18,83220023
2090	0,185009034	10%	0,002981672	0,18516318	18,51631803
2091	0,18192548	10%	0,00291393	0,182095104	18,20951039
2092	0,178893321	10%	0,002881605	0,179043876	17,90438757
2093	0,175911698	10%	0,00281896	0,176074361	17,60743613
2094	0,172979771	10%	0,002785132	0,173126567	17,31265668
2095	0,17009671	10%	0,002726872	0,170252899	17,02528992
2096	0,167261701	10%	0,002692079	0,167404631	16,74046309
2097	0,164473943	10%	0,002637619	0,164624081	16,46240813
2098	0,161732649	10%	0,002602289	0,161871653	16,18716534
2099	0,159037044	10%	0,002551149	0,1591815	15,91815001
2100	0,156386367	10%	0,00251562	0,156521424	15,65214239

Appendix E: List of interviewees

Number	Name	Job description	Date of interview
1	Henk van Hardeveld	Team leader Hydrology & Ecology at Waternet	08-05-2020
2	Wes Korrel	Organic dairy farmer in the Rondehoep	13-05-2020
3	Mart Kea	Cattle farmer in the Rondehoep & Vice-chairman for LTO	13-05-2020
4	Rinus Hofs	Flora and Fauna advisor for the Municipality of Amstelveen	20-05-2020
5	Ernest Briët	Director at Stichting Landschap Noord-Holland	28-05-2020
6	Janny Gerritsen	Policy advisor Food Vision, Soil subsidence and Green Heart at the Province of North Holland	28-05-2020
7	Renske Peters	Chair Stichting Beschermers Amstelland	29-05-2020
8	Matthijs Boeschoten	Project & Business Developer at Wij.land	03-06-2020
9	David Kloet	Partner/Landscape architect at Karres en Brands	05-06-2020

Appendix F: Interview questions

Introduction:
I'm Lotte van Helden, and I'm working on my Master's degree in Water Science and Management at Utrecht University. My thesis is about the future of the peat meadow area in the Green Heart. This is an area where many complex issues come together: soil subsidence, water, nitrogen, biodiversity and the housing challenge. My research focuses mainly on the problems of soil subsidence.

Climate change and increasing water management costs call for a new vision on how to tackle soil subsidence in the Green Heart. Steering Group Green Heart has commissioned several landscape architects to carry out a 'design study' to see how the Green Heart can be transformed into a balanced and adaptive landscape. Currently, the form of land use determines what water management is needed. RWA Amstel Gooi and Vecht (AGV) has decided that from 2030 onwards only 75% of the soil subsidence will be followed by a lowering of the level, whereby facilitating the current land use remains the starting point. However, in the distant future the non-automatic lowering of water levels may mean that livestock farming will no longer be possible in parts of the peat meadow area. By studying what will happen if water management is set up to stop or reduce subsidence and CO_2 emissions, whereby land use adapts, a new perspective is created.

The scenarios were created by thinking about possible solutions with the regional stakeholders and experts. The following starting points were the most important:
1. For soil: minimizing soil subsidence and greenhouse gas emissions
2. For water: minimizing water demand and flooding

It has been studied how maximum contributions can be made to the realization of these starting points within the two different future scenarios (production landscape and natural landscape). To this end, an overall spatial design was first made and then an estimate was made of the effects on soil subsidence, greenhouse gas emissions, water shortage, excess water, biodiversity and landscape.

The scenarios are explicitly intended as thought models, not as practical proposals for spatial policy. I want to use these scenarios to explore what a realistic picture of the future might look like; what measures would they contain, what could this mean for you/your organization and what input (money, knowledge, etc.) would be needed to realize it?

- Would you like to introduce yourself first? (name, organization, function etc.)
- Which trends are playing a role in your organization (e.g. climate change, soil subsidence, energy transition)?
- Do you notice soil subsidence in your work?
- Does your organization think it is important that something is done about it?
- Is your organization already taking measures to tackle subsidence? (If not: on what time scale does your organization expect to make changes?)
- What do you think is feasible for the peat meadow area in the short term?
- What do you think is desirable for the peat meadow area in the long term?

Show scenarios (Appendix B): first introduce where these scenarios come from, ask whether they are familiar with the scenarios.

<u>Reference scenario (extend current policy until 2050)</u>
- Is this a realistic picture?

- What are the consequences of the reference scenario for your organization? (Can you link a timeline to this?)
- In other words; is this scenario sustainable, or is there a time limit?

<u>Scenario Production landscape</u>

Stakeholder	Measure
Regional water authority	• Raising the water level • Level fluctuation • Local embankment with clay and/or city compost along the storage basin • Construction of water retention in polders
Farmer	• Construction of submerged drainage • Changing from business model to nature-inclusive agriculture • Changing from business model to wet crops

Land use change
Land-based dairy farming → Paludiculture (retention basin)
Land-based dairy farming → Nature-inclusive livestock farming with submerged drainage
Edges of storage basin with buildings → Edges of storage basin with city gardens

- What is your first reaction?
- What could this scenario mean for your organization?
- What does your organization need to implement these measures?
- Is all the necessary knowledge present for this scenario?
- Do you consider this scenario financially feasible?
- Is there support for this scenario?
- On what time scale do you expect to be able to make changes?
- Where do you think the risks lie?

<u>Scenario Nature landscape</u>

Stakeholder	Measure
Regional water authority	• Active wetting of peat • Rainwater retention in the area
Farmer	• Changing business model (or move away)

Land use change
Land-based dairy farming → emergency spillway with reed growth and forest
Land-based dairy farming → peat meadow decoupled from storage basin - peat moss growth

- What is your first reaction?
- What could this scenario mean for your organization?
- What does your organization need to implement these measures?
- Is all the necessary knowledge present for this scenario?
- Do you consider this scenario financially feasible?
- Is there support for this scenario?
- On what time scale do you expect to be able to make changes?
- Where do you think the risks lie?

If we forget about the scenarios for a moment, what do you think is needed in the area as a whole?

Questions for policymakers:

- What will happen in the future?
- What policy moments are coming (new water level management, area visions, etc.)?
- Are you also looking at other policy objectives (such as housing, energy transition) (these are missing in these scenarios)?

Wrap-up

- Are there topics that have not yet been discussed and that you would like to discuss?
- I may have some additional questions at a later time. Could I approach you for that?