Limitations and possibilities of Dynamic Adaptive Pathways as a planning approach regarding Salinization

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Colophon

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Abstract

The Netherlands is expected to face substantial changes to its climate and landscape due to the destabilizing effects as a consequence of global climate change. These changes are likely to impact the possible function and land-use of certain places in the Netherlands. What, where, when and to what extent these changes will occur is clouded by uncertainty. Based on recent climate events, experts can make preliminary assumptions on what is most likely to happen. Climate change is expected to destabilise the current climate, increase precipitations in winter and decrease precipitation in summer. This will increase vulnerability for both flooding and droughts. Dutch water management planners have ample experience with: flood protection, land reclamation and drainage. Or in other words, managing excess water. Drought management, on the other hand, is an aspect of water management that, until recently, did not receive the same priority. The phenomena of drought, brings new challenges to the planning field, that Dutch planners have less experience with. One such challenge is salinization. In periods of low precipitation, saline water seeps up to the surface water. Causing the fresh surface water to become brackish or even completely saltwater. Most crops are unable to grow in these conditions and high salt concentrations have long term damaging effects on clay soils. Without planning intervention, the process of salinization will amplify the negative consequences of climate change. When water related phenomenon change, a transition in water management is required. The Dynamic Adaptive Policy Pathways approach (DAPP) is a planning approach that has been implemented in more general water management planning. To gauge weather or not the DAPP approach would add value for planners dealing with salinization, mixed methods were implemented. Academic and grey literature was consulted, and interviews were conducted with various stakeholders. Resulting in an overview of measures with varying in implementability. Eventually too little measures could be identified at all stages of salinization to create one or more definitive pathways. Although the most desirable outcome would be that a pathway can be chosen, we now have a better idea of the type of measures we have and who is responsible for implementation. The gaps in the final DAPP model do show us in what cases we are unprotected against salinization. Creating insight into vulnerabilities and reducing uncertainty. In addition to this, the gaps in the DAPP model can be used as a base to implement more specific future research.

Key words

Salinization, Dynamic Adaptive Policy Pathways, Transitions, Tipping points.

TABLE OF CONTENTS

List of Figures

List of tables

1. Introduction

It became known in recent years that climate change is expected to bring substantial changes to the Dutch climate. These expected changes include changes in precipitation patterns, with an increase in precipitation in winter and an increase of droughts in summer (Tilburg & Hudson, 2022). This requires a shift from traditional forms of water management that focus on water drainage towards an approach that can deal with seasonal weather extremes. In the ideal situation the Netherlands does not flood in winter, while having fresh water available for drinking, irrigation, shipping and industry in summer. To create an understanding of the impact of climate change in the Netherlands, first an overview of the historical KNMI data is provided. Followed by more recent weather data and the consequences of the changing weather patterns.

The Netherlands traditionally has a temperate maritime climate with four distinct seasons. Namely summer, autumn, winter and spring (KNMI, 2021). Mild summers and winters and precipitation all year round (Klimaatinfo n.d.; Murigi, 2018). The mean temperature in summer is lower than 22 degrees Celsius and in winter the mean temperature is higher than 0 degrees Celsius (Murigi, 2018). Maritime climates generally lay besides a large body of water. This body of water has a regulating effect on the temperature on land, due to winds coming on and offshore (Murigi, 2018). For the Netherlands this large body of water is the North sea, that is located on the West and North coast of the country. The North sea is responsible for most of the wind in the Netherlands. In winter it creates atmospheric depressions which could lead to storms. These storms most commonly occur in January or February. The Netherlands is not susceptible to hurricanes, as hurricanes are measured by measuring mean windspeed, however wind blasts are common.

The Koninklijk Nederlands Meteorologisch Instituut (KNMI) translated to Royal Dutch Meteorological Institute researches the Dutch climate and compares the results over time. For the report Klimaatsignaal '21, the average climate and weather patterns of 1961-1990 and 1991-2020 are compared to each other. The following changes have been reported (KNMI 2021). Between the time periods of 1961-1990 and 1991-2020 the average temperature over an entire year has increased by 1,1 degrees Celsius in the Netherlands, which is more than double the global increase average. Temperature increases were observed in all seasons, however differences were biggest in spring. Average solar radiation over the entire year has increased, whilst average windspeeds have decreased. Annual precipitation did grow by eight percent, mainly due to an increase in winter and summer. There was no upwards trajectory in the number of rain days, however the intensity of precipitation did increase. In spring the number of days with precipitation decreased leading to a total decline in precipitation for this season. The decrease in precipitation and increase in dry and sunny days with higher temperatures is a process that has been observed over time. Due to its cumulative effects, it has led to an precipitation deficit in spring and summer. This precipitation deficit occurred during the grow season for crops which takes place from April first to November first. During winter the number of days with a minimal temperature below freezing point was reduced by twelve days. The number of days with a maximal temperature below freezing point was reduced by five days. The number of days with high precipitation increased with one day. In summer the number of days with a temperature of 25 degrees Celsius and higher increased by nine days, whilst the number of tropical days with a temperature of 30 degrees Celsius increased by 2,6 days. The highest temperature recorded increased by 2,4 degrees Celsius between 1990-2020 compared to in the period 1961-1990. The number of days with high precipitation increased by 0,4 days. The least amount of change was reported in autumn, with the main point being a reduction in precipitation since the year 2000 (KNMI Klimaatsignaal '21).

As 2024 is still ongoing, only preliminary reports have been published. Therefore, we will take a look at the most recent year where the final report has been published, 2023. In the winter of 2023, the Netherlands experienced unusually high precipitation (KNMI - Jaar 2023, 2024), leading to flooding in multiple parts of the country. Farmers could not enter their fields with large equipment. This negatively impacted the harvesting process. The water seeped into houses, increasing humidity, causing Mold. In 2023 the spring was very dry (KNMI - Jaar 2023, 2024). Which lies in a general trend where the prevalence of droughts increased in the Netherlands during spring and summer.

Droughts can have various negative impact on the environment. Droughts can cause damage to houses, roads, and nature next to damage to dykes. By drought damaged dykes increase flood risks in winter. The Netherlands is classified as a highly vulnerable delta region, susceptible to the negative impacts of climate change (Kamperman & Biesbroek 2017; Barlow and Reichard, 2010; Giambastiani et al., 2007; Bobba, 2002; Meisler et al., 1984; Ranjan et al., 2006). With the negative impact droughts have on flood protection, the risk caused by this vulnerability increases. Different levels of government are already implementing mitigating measures. These measures mainly aim to hold on to the water in spring, to ensure that there is a large reserve in summer. For humans the biggest risk is the lack of freshwater that is used for drinking water, agriculture, shipping and nature conservation. These functions are all limited when little fresh water is available. Prioritization of function is required to ensure that during drought, functions with the highest priority are serviced first. It is important, however, to take into account the long-term consequences of prioritization.

When the prevalence of droughts increases, the phenomenon of salinization can occur. This phenomenon negatively impacts water quality in affected regions (Chiarelli et al, 2024). Long term, this can lead to reduction of soil fertility subsequently leading to a reduction of crop yields, or even making the land unsuitable for cultivation (Chiarelli et al, 2024; Karimzadeh et al, 2024). Reduction of crop yields can have long and short-term impacts on availability of certain types of food and raw materials, in addition to reduced profits in agricultural industries. Eventually this can lead to reduced availability of specific food groups. As stated before, Dutch planners already have an extensive knowledge of flood protection. To the extent that Dutch planners in coastal protection work all over the world to aid other countries in coastal protection and land reclamation. However, dealing with droughts is a new and upcoming aspect of Dutch water management. Even less researched are the consequences of drought, salinization, within the Netherlands.

Traditional forms of strategic planning tend to focus on a single future situation (Enzmann et al., 2011). This envisioned situation can be desirable or undesirable, with planners developing steps to either reach or prevent this situation (Enzmann et al., 2011). The downside of this straightforward planning method is that if any variable changes, the plan needs to change, instigating a completely new planning cycle. These kind of traditional forms of planning work when dealing with straightforward situations that have little uncertainty. Climate change decreases the stability of the climate, therefore increasing uncertainty (Ebi, 2021). To ensure that the right measures are implemented at the right time, a transition away from traditional planning needs to be made.

1.1 RESEARCH APPROACH AND OBJECTIVES

Implementation of various adaptative and mitigation measures to combat the consequences of climate change is one of the many responsibilities' planners in all levels of government are currently dealing with. Implementing measures might be costly. When planners are implementing measures with public funding and in public spaces, it requires an approach to the issue at hand that ensures resources are spent appropriately. With increased uncertainty due to the various implications of climate change, decision making is often postponed until there is more clarity. Additionally traditional forms of planning (Enzmann et al., 2011) or bureaucracy (Huitema et al. 2011) might be in the way of timely decision making and implementation. However, this leaves planners with little time to implement adaptative or mitigating measures to rectify the problem at hand. A comprehensive planning approach is required to aid planners in decision making on issues clouded with uncertainty. Adaptation approaches are represented as promising approaches in situations surrounding uncertainty in academic literature. Especially the Dynamic Adaptive Policy Pathways Approach, developed by Haasnoot et al, (2013) has managed to gather some attention in academic literature. Zandvoort et al, (2019) states that it is implemented in various fields, such as energy planning, climate adaptation planning (Spaan & Lieftink, 2022), and water management (Haasnoot et al, 2013), in their paper aiming to answer the question how the DAPP approach would function in spatial design. The majority of research surrounding the DAPP approach, implements the approach for broad and general objectives. However, if the approach would be suitable for a specific issue within water management or climate change adaptation has not been researched as of today. From this perspective it would be interesting to see whether or not the DAPP approach could be a beneficial approach in dealing with salinization. On the other hand, salinization is a complex consequence of natural hydrological processes and heavily exacerbated by climate change. Globally a lot of research has been done to try and solve this problem. However, salinization can have different causes. The type of salinization present in the Netherlands and the specific implications of salinization on the Dutch landscape have not been thoroughly researched in academic settings. Even though practical research is being done on trial farms throughout the country, there is no research surrounding a holistic approach to salinization, that also takes into account how governance should be implemented. Combining the questions from both the, further development of the DAPP, perspective and the, increase an understanding solution for salinization, perspective would lead to

''What is the potential of the Dynamic Adaptive Policy Pathways approach to aid planners in preventing the negative outcomes of Salinization in the north of the Netherlands?''

With the sub-questions being; ''what is salinisation & what can planners do to prevent it?", ''What are Dynamic Adaptive Policy Pathways & how does this tool relate to salinisation?".

2. Theoretical Framework

To create an understanding of the impact of the Dynamic Adaptive Policy Pathways approach on Salinization prevention, both the concept of the DAPP and the phenomenon of salinization need to be understood. This chapter starts by providing an overview of the research on salinization, how the issue is currently being approached by governments and then it will explain what a Dynamic Adaptive Policy Pathways approach is and how it would interlink with salinization.

Global changes in land use, changing use of energy and an increase in greenhouse gas emissions have led to a situation where global weather patterns are changing (Ebi, 2021). These changes are defined as climate change. Climate change is partly a natural process, however, this process is vastly accelerated by human actions. Due to the human impact on the climate, some scientist identify the current geological time-period as the Anthropocene (Letcher, 2015; Ebi, 2021). Changes occur on both on a day to day basis, such as changes in temperature or precipitation patterns, but there is also an increase in extreme weather events such as heat waves, droughts or floods (Ebi, 2021; Tilburg & Hudson, 2022). Climate change has an impact on (marine) ecology, biology (Letcher, 2015) and human communities (Letcher, 2015; Ebi, 2021). Local implications of climate change depend on the environmental context. For example, delta regions are more susceptible to flooding and salinization as negative impacts of climate change (Kamperman & Biesbroek 2017). In dryer climates, the prevalence of wildfires can increase due to climate change (Ebi, 2021). Heat waves can cause heat strokes and death in elderly citizens (Xu,. Et al, 2019), crop failures and even has negative impact on animals. Droughts can make dykes unreliable. Heavy precipitation can cause floods (Kamperman & Biesbroek, 2017). That climate change will have an impact is clear, however, what, how, when and where is still surrounded by uncertainty.

2.1 SALINIZATION

Salinization is a naturally occurring process in coastal areas (Louw et, al. 2010). Salinization is a hydrological phenomenon that allows salt water from the sea to enter the freshwater table land inwards. The speed of this process is limited by the availability of fresh water (Chiarelli et al, 2024 ; Stowa n.d. 1b). Salinization can occur in various ways. It is influenced by long term hydrological processes and events such as land subsidence, groundwater extraction and land reclamation (Essink, et al. 2010). Coastal areas can be affected by spray, when the wind blows particles of sea water land inwards (Stuyfzand and Stuurman, 1994). Salinization can also occur below ground level through seawater intrusion (Stuyfzand and Stuurman, 1994), or saline seepage (De Louw, et al. 2013).

For the Netherlands two types of salinization are relevant. One being external salinization or river transgression (Stuyfzand and Stuurman, 1994; Louw et, al. 2010). River transgression occurs when salt water from the sea flows inwards through the freshwater rivers, when freshwater output is low. Salt water is heavier than freshwater, therefore the saltwater flows over the river basin, freshwater flows over this salt water. This phenomenon is defined as a 'salt tongue' (Informatiepunt leefomgeving, 2024). The main risk of this type of salinization is that the saltwater intrusion occurs so far upstream that it reaches water inlets for drinking water facilities or industrial functions. This type of salinization can be flushed out by increasing freshwater flow, if and when this water is available (Stuyfzand and Stuurman, 1994). The other type of salinization occurring in the Netherlands is upwards seepage of the groundwater. Upwards seepage occurs when salt ground water, pushed land inwards from the sea, seeps upwards to the surface equalling mean sea level (De Louw, et al. 2013). In addition to the underground push from the sea, the Netherlands has historically and currently still is, located below sea level, large areas of land would regularly flood. During these floodings salt water could infiltrate the sandy soils of the Netherlands (STOWA N.D. 1b). Salinization impacts the water quality. Saline or brackish water is not suitable for drinking water, water used for irrigation or for nature conservation (Chiarelli et al, 2024; Karimzadeh et al, 2024). Meaning that the availability of fresh water in summer will decrease. Costs of water purification will increase as less fresh water is available. In extreme cases, leaving clean drinking water unavailable for those who cannot afford it. In the Netherlands prices of drinking water already increased, due to the increased costs of water purification (NOS, 2023). Adding more pollutants, such as high salt concentrations would make the costs go up even higher (Chiarelli et al, 2024). Groundwater salinization and seepage has been a major water quality problem for a long time (Louw et, al. 2010). Shedding a light on the complexity of solving this water management issue. Various attempts at solving it have been made (STOWA, n.d. 1b), however, there is no holistic solution implemented as of yet.

An additional risk occurs when, during dry spells or droughts, upwards seepage occurs at an increased pace, as there is no freshwater lens to push down this upwards seepage. Louw et, al. state that this process makes the surface water unfit for irrigation, in addition to this, it has a negative impact on aquatic ecosystems (2010). This salt water seepage could reach shallow ground water, surface water and the root zone (STOWA, n.d. 1b).

When precipitation levels are high, enough fresh water is available to preserve a balance between salt and fresh water. In Figure 1, it can be seen that the salt water, in red, is moving upwards. Freshwater, in blue, is pushing down. As long as this freshwater lens is maintained, roots are able to grow in freshwater. As seen in the figure 1, both fresh and saltwater move towards ditches. This brackish water can create problems with irrigation. As long as there is enough freshwater available, the water would remain fresh enough, not to cause issues.

Changing precipitation patterns due to climate change, in addition to rising sea levels are expected to speed up this process, affecting the balance of fresh and salt water. For the Netherlands such a balance has yet to take place (Essink, et al. 2010). The process of salinization is susceptible to changes in the environment. Considering this, the increase of mean sea level and changes in precipitation patterns due to climate change, a stabilisation of this process on the short term is unlikely. The increase of mean sea level and especially periods of low precipitation, or droughts, have an accelerating affect on saline seepage (De Louw, et al. 2013; STOWA, n.d. 1b).

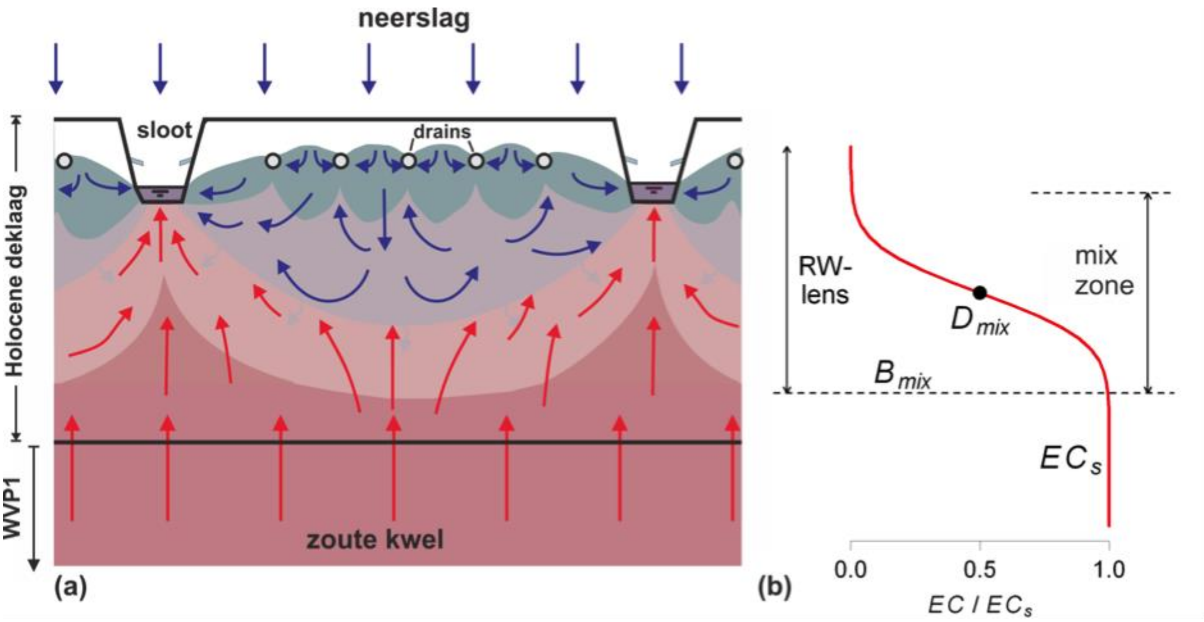


Figure 1, STOWA, n.d. 1b. Saline Seepage, in Dutch.

Saline seepage has the potential to have a devastating effect on agricultural processes and crop yields. The top layer of water is referred to as the root zone or soil moisture and is used in agriculture for farming (STOWA, n.d. 1b). When this layer is filled with freshwater, various types of crops are able to grow there. When saline seepage reaches this top layer of soil moisture, the types of crop that can grow there are limited to species that are able to handle high salt concentrations (De Louw, et al. 2013). To prevent saline water from reaching the surface a water freshwater buffer is required. Freshwater lenses occur at a depth from 5 to 100 meters into the ground, they commonly are brackish because they come into contact with saline seepage. Rainwater lenses only infiltrate to about 3 meters into the ground. These rainwater lenses remain freshwater lenses as long as they are replenished regularly (STOWA, n.d, 1b).

Solutions for salinisation vary depending on the type of soil and reason why salinisation occurs. In sandy soils, for example, it is possible to flush out the high salt concentrations as sandy soils are highly permeable. For peat, clay or other low permeable soils, flushing out the high concentrations of salt is not an option. Operations to reverse salinisation will be very costly and therefore the salinization should be prevented as much as possible (Cherlinka, 2021; STOWA, n.d. 1a; STOWA, n.d. 1b).

There are various strategies that can prevent salinisation;

(*1*) *Irrigation to ensure that soil is saturated with water*. This limits the opportunity salt water has to migrate further land inwards. In agriculture this can be done by implementing drip irrigation (Karimzadeh et al., 2024). Another way to ensure that the soil is saturated with water is to reuse wastewater (Rebhun, 2004). Reusing fresh water is essential when the availability of new fresh water is limited (Rebhun, 2004) however, even when fresh water is available reusage is still implemented. Side effects of implementing this measure is that the water is not suited for every function. Planners should be warry of consequences to public health and negative impacts on crops and ecology. However, with proper procedures in place, this practice should be safe. In regions where freshwater availability is not limited, wastewater also gets processed before it is dumped in surface water. Wastewater treatment plants in the Netherlands do not purify the water to the extent that it is drinkable, but recreational use of surface water is possible.

(*2*) *capturing and treating salt water*. If freshwater is unavailable salt water can be collected and treated to a level where the water can be used for agriculture, drinking water or other functions. This is an expensive process (Stuyfzand, 2005)

(3) *Drought management through international relations.* The Netherlands always had to work hard to get rid of excess water. Due to precipitation changes droughts are likely to increase in occurrence. For many other countries, droughts are not uncommon, they might have technical solutions that are not widely researched. The Netherlands could work with these countries to learn from their expertise, just as the Netherlands is exporting expertise on water management aspects as waterfront protection (Deltaprogramma, 2019; De Gelderlander, 2017). The Netherlands is not the only country affected by internal and external salinization. Countries that are affected by the same types of salinization might have found measures or approaches that aid in dealing with salinization. These measures are not represented in academic literature. International collaboration and discussions surrounding this topic might bring new measures and perspectives to Dutch planners.

When salinization is already present in the landscape measures can be implemented that either slightly reverse the process of salinization (STOWA, n.d. 1b) or the use or function of the area can be changed by implementing the following measures.

(*1*) *Saline cultivation*. If freshwater availability is low, and soils are not suitable for cultivation, agriculture needs to shift from traditional crops to saline cultivation. Many delta regions in Southeast Asia are affected by salinization. Local farmers have shifted their fresh water dependent rice crop towards a salt water dependent shrimp farm (What Can We Do About Salinization Of Soils? Ensia, 2019). In the Netherlands various pilots surrounding saline crop cultivation are currently ongoing (STOWA, n.d. 1a)

(2) *Closed system agriculture*. Traditional forms of agriculture found in the Netherlands, require land and vast amount of fresh water. A way to reduce both of these requirements is to implement close system agriculture. This can be done by growing food in greenhouses or even implementing aquaponic systems where crops are grown in water instead of soil. In an ideal aquaponic system, there is a fish tank looped into the system. Fish are fed, these fish produce manure, the fish manure is transported through the water to the plants to be used as plant fertiliser. With a system of filters the water can be reused over time and depending on the suitability of the type of fish, the system can be used for both fish and crop cultivation (Palm, 2018). Aquaponic systems require less space than traditional agriculture, therefore they can be implemented closer to urban environment (love et al, 2015), reducing transport related emissions, or leave more room for other functions in the area. It is important to take into account that these systems do require heating, and therefore are more profitable in warmer climates (love, 2015).

(*3*) *Aquifer storage and recovery.* ASR is a technical solution where freshwater is pushed into underground aquifer during times when freshwater is abundantly available, to be stored and recovered during times when little freshwater is available. In this manner, freshwater can be stored for long periods of time, with little risk of pollution. Underground temperatures are stable, and water does not evaporate. Underground storage frees up space above ground, which can be used for other functions (Zuurbier et al., 2014). Implementation of ASR systems is relatively expensive compared to traditional small-scale drainage and irrigation systems. Therefore, it might be more beneficial to implement ASR systems on a larger scale.

(*4*) *Electric sieve.* A technical solution can be implementing a vertical electrokinetic system (V-EK). This system requires a multilayer electrode to be placed in soil, to form an electric sieve. The salt water is impacted by the electric pulses from the electric sieve. The salt is pulled downwards, reducing the impact of salinization in the top layer of soil, where crops grow. Research has shown that an electric sieve can reduce salinization about 99 percent compared to controls (Li et al, 2022). It is important to understand that this approach is still in the developmental stage and therefore is not ready for full scale implementation yet. An electric sieve should not be implemented in a plan of action, as it is unknown if it will work in practice and if it will work for every soil type.

Considering the available literature on salinization there are knowns and unknowns. The information and the information gap can be divided into what will happen, when it will happen and how it can be prevented or dealt with.

The general process of salinization and the consequences are explained in the literature. What is missing is the specific impact of salinization and the consequences. For example, what type of vegetation or crop can deal with high salt concentrations. It might be possible that salinization cause externalities that we do not know about yet. With the majority of salinization research concerning irrigation, the question remains what the impact of salinization will be on ecology and the built environment. Then we also do not know at what pace the process will occur. As salinization is heavily dependent on precipitation patterns. Proposed solutions are mainly focused on implementing physical measures. The downside of this is that these measures are not widely implemented, if they are implemented at all. Therefore, it is unknown if they have the desired effects. Adding more uncertainty for planners who are responsible for deciding if and when these measures are implemented. Uncertainties surrounding salinization mainly lay in not knowing when changes will occur. Implementing costly measures without a timeline is therefore not desirable.

2.2 DROUGHT MANAGEMENT APPROACH

In the Netherlands drought management is regulated by three governmental bodies, the Ministry of Infrastructure and water management, the Province and the Water boards. The ministry of Infrastructure and water management has published a water allocation plan for the Netherlands during periods of drought (Verdringingsreeks: Rangorde Bij Waterschaarste, 2021). This allocation plan is a tool for governmental bodies to act immediately when droughts occur. All parties know what is expected of them and when they need to act. Stakeholders know what priority they are, and they can plan accordingly. In the decree ''Quality of Living Environment'' that came into effect on January first 2024, the categories are defined and the priority in category one and two are established (Wetten Overheid, 2024). The priority in categories three and four are not set in stone. Category one and two, Table 1, need to be followed from lowest number to highest number. The province is allowed to change the priorities within the categories 3 and 4, however they are not allowed to shift between these categories (Verdringingsreeks: Rangorde Bij Waterschaarste, 2021) as represented in Table 1.

Category 1	Category 2	Category 3	Category 4
Safety and prevention of irreversible damage	Utilities	Small-scale high-quality use	Other interests, economic consideration and nature.
1. Stability of flood defences 2. Prevention of settlement and settlement 3. Prevention of irreversible damage to nature (otherwise cat. 4)	1. Drinking water supply (to guarantee security of supply, otherwise cat. 4) 2. Energy supply (only if there is a risk to security of supply, otherwise cat. 4)	• Temporary irrigation of capital-intensive crops • Process water	• Shipping • Agriculture • Nature (provided no irreversible damage occurs) • Industry • Water recreation • Inland fishing • Drinking water supply (other than cat. 2) • Energy supply (other than cat. 2) • Other interests

Table 1 (Verdringingsreeks: Rangorde Bij Waterschaarste, 2021)

Numerous measures can be implemented in both the private sector and in various levels of government. To ensure an efficient and effective implementation of measures a governmental framework is required. Within this framework, Table 1, responsibilities can be allocated. When private parties decide on measures, communication and coordination with governments may aid the process. For example, if a farmer wants to implement closed circle agriculture, they have to build greenhouses. The municipality is responsible for zoning plans that dictate if a plot of land is allocated as farmland or if building is allowed. By collaboration, such plans can be realised much sooner. When closed agriculture is implemented, water usage will be reduced. Water boards can allocate the water that previously went to irrigation to other functions. If this reduction in water usage happens on a larger scale, the province might shift the priority of agricultural water within category three and four (Verdringingsreeks: Rangorde Bij Waterschaarste, 2021).

2.3 CONCEPTUAL MODEL

Starting from the current situation Dutch landscapes are likely going to experience a change due to two factors, natural hydrological processes such as upwards seepage and climate change. Upwards seepage does not necessarily result in salinized soils, however due to the destabilizing effects of climate change, the process of upwards seepage can be exacerbated, resulting in saline soils. The two factors that will have the most impact on upwards seepage are mean sea level and precipitation patterns. These factors are heavily impacted by climate change. We know that these factors will change, when and to what extent this will happen is still clouded with uncertainty. Combining these concepts leads us to Figure 2.

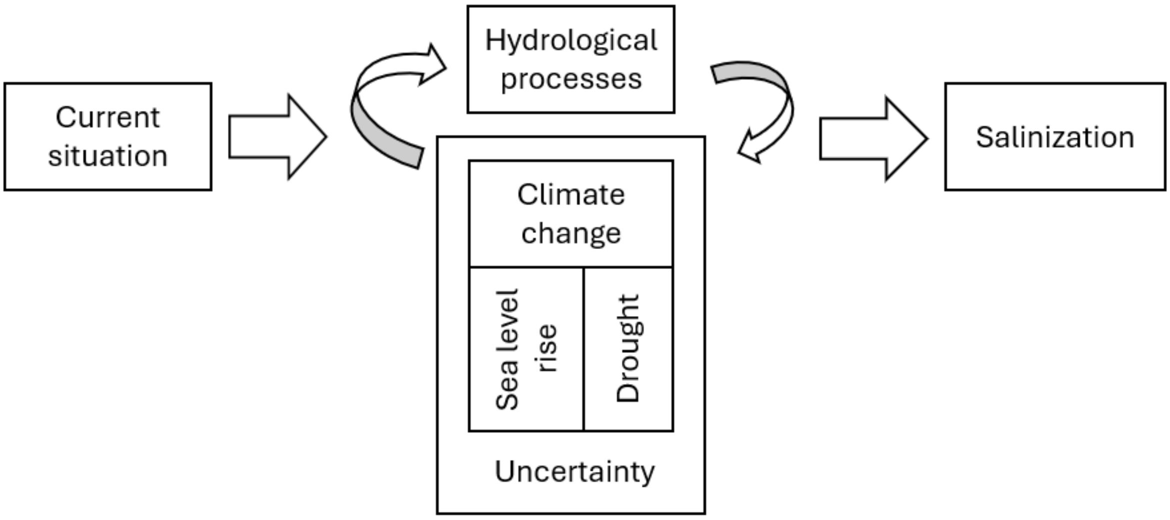


Figure 2 How does salinization occur, own source

The current landscape, the process of salinization and planning approach together lead to an outcome Figure 3. If the outcome is undesirable one of the input variables needs to be changed. The current landscape changes due to exogenous factors such as planning practices or naturally occurring phenomenon such as salinization. Salinization is impacted by other factors such as climate change. Meaning that the only aspect of the equation that planners can directly influence is the planning approach. If planners want to ensure that the desired outcome is reached, they should start with changing the planning approach.

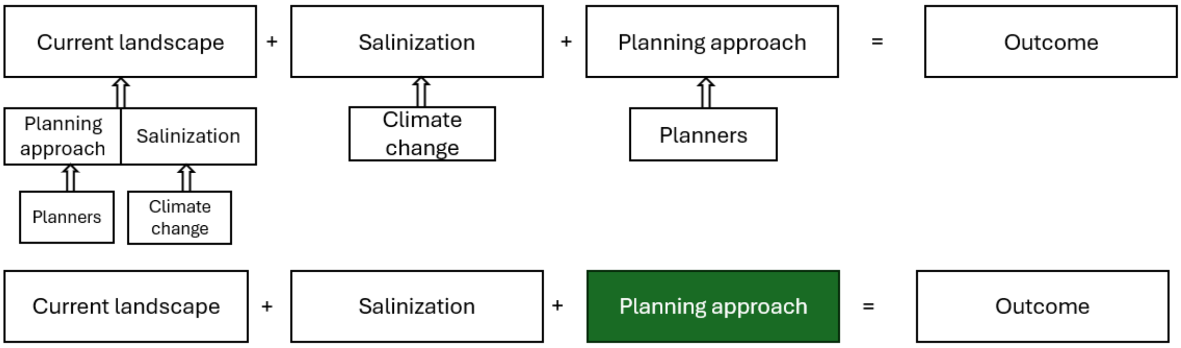


Figure 3 Conceptual model why intervention is required, own source

Changes in the planning environment, like climate change and in the context of this salinization, demand a change in planning practices. Traditionally planning aims to either prevent of reach a certain (un)desirable future situation (Enzmann MD et al., 2011). This straightforward method is dependent on certain variables, such as Salinization and planning approaches. In certain situations, decision making can be based on objective criteria. When the situation is more fluid, implementing objective criteria in decision making is more complicated. De Roo (2020) identifies these complicated situations, described by Enzmann MD et al., (2011) as Complex situations or fuzzy situations. Simple situations have very little stakeholders involved in the process The variables surrounding the process are predictable or certain. Decision-making is relatively easy and mainly focus on technical solutions. On the other hand, is complexity. Complexity or complex situations are surrounded by uncertainty and various stakeholders (De Roo, 2020; De Roo 2018). Planners ought to work through complex situations by implementing communicative approaches, where stakeholders reach the decisions together. Through discussion the problem, the and the goal is identified. Externalities can be taken into account. Measures can be discussed, and responsibilities can be divided. The communicative approach is non-linear where the process is more important than the outcome. Situations such as climate change are surrounded by uncertainty, demanding a shift in planning approaches to move away from traditional (Enzmann MD et al., 2011) or technical approaches (De Roo, 2020; De Roo 2018). These communicative approaches differ from traditional or technical approaches as communicative approaches are non-linear approaches. Through discussion the problem and the desired outcome are identified, and a plan is developed. After the process starts, steps are evaluated and together stakeholders decide on weather or not the original plan will be followed, or new measures will be implemented (Roo 2018). In water management, issues have been approached through adaptation strategies for a while (Deltares, n.d. 1b). Adaptation strategies, such as other forms of communicative planning, aim to shift the focus from results to decision making (Haasnoot et al. 2013; Zandvoort et. a., 2019). A shift towards decision making would assist planners when unexpected events occur during the planning making process. They also assist planners when dealing with planning processes surrounded by uncertainty.

Currently multiple levels of government are responsible for different aspects of drought management. There is no set governmental body responsible for salinization. The vague scope of responsibilities and the uncertainty of the speed and the impact of salinization together requires a planning intervention. As the process of salinization is highly dependent on somewhat unpredictable weather events such as precipitation, the planning intervention needs to be flexible. Traditional approaches to planning are not suitable in situations that require flexibility (Enzmann MD et al., 2011), therefore a new planning approach is required.

2.4 DYNAMIC ADAPTIVE POLICY PATHWAYS APPROACH

Solving climate related planning problems have proven to be a complicated task. From 1970 onwards, planners implemented Integrated Assessment Model (IAM) as a tool to aid them in both, creating an understanding of measures through models, and developing policy based on the outcome of these models. Modelling can be done through extrapolating current trends to find a most realistic future outcome. IAMs are simulations that are able to model the complex relation between the natural system and policies implemented into that system. The goal of IAMs is to aid planners in policymaking. IAMs could test the impact of policy to see weather the results of specific policies where desirable. IPCC used this approach to calculate weather or not current proposed measures would be sufficient in reaching the goal of keeping the global temperature increase below at least two degrees Celsius with 1,5 degrees Celsius being a more desirable outcome. This agreement is commonly known as the Paris Agreement (UNFCCC, 2015).

Another way IAM are implemented is to gauge weather or not the cost implementing measures would be outweighed by the benefits of implementing measures. Leading to an optimal mitigation level, relative to costs of climate impacts. highly aggregated cost-benefit IAM that estimate optimal mitigation levels relative to economic costs of climate impacts (Beek et. al., 2020). IAM come in several forms and are described as flexible and comprehensive. Combining multiple IAMs together, an Integrated Assessment Meta Model (IAMM) can be created. The IAM seem to be a valuable tool in the toolbox of planners and decision makers that want to better understand and evaluate the impact of their measures, before implementation in either policy or practice. Planners implementing IAMs assume that the future is predictable, as long as the right input is present (Haasnoot, 2013) however, this is not always the case. Reality always has uncertainties, ignoring these uncertainties can lead to inaccuracies that do not align with reality anymore McInerney et al. (2012). Modelling this new situation takes up too much time (Haasnoot, 2012), leaving planners unprepared and leading to Impromptu decision-making (Haasnoot, 2013). These downsides to IAMs require a different planning tool that is able to aid planners in decision-making trough uncertainty. One proposed planning approach is the Dynamic Adaptive Policy Approach, developed by Haasnoot, et al. (2013).

Dynamic Adaptive Policy Pathways (DAPP) is a new planning approach that aims to assist planners in situations of uncertainty (Haasnoot et al. 2013). DAPP's represent a shift from understanding climate change to risk management, through implementation of mitigating or adaptive measures (Kwakkel et al. 2016). Traditional forms of planning work towards a most likely future scenario (Michas et. al. 2020) or future scenario models (Kwakkel et al. 2016). Climate change brings deep uncertainties, making it impossible to create plans based on scenarios (Kwakkel et al. 2016). DAPP's aim to create a strategic vision of the future containing both a long-term framework for decision making and short term action plan. The framework is designed to be flexible to ensure that planners are able to deal with uncertainty and changing circumstances (Haasnoot, et al. 2013). Dynamic Adaptive Policy Pathways are based on two approaches, Adaptive Policymaking and Adaptation Pathways. Adaptive Policymaking describes different types of actions, such as mitigation. In adaptive policymaking evaluation of measures is required. Adaptation Pathways are an approach to explore sequences of possible measures, based on alternative external developments (Haasnoot et al. 2013).

The process of developing a Dynamic Adaptive Policy Pathways goes as follows. (*1*) Analyse objectives, vulnerabilities and opportunities using scenarios. (*2*) Identify actions and assess efficacy and use-by year of actions. (3) Develop and evaluate adaptation pathways and map. (4) Design of an adaptive plan, including preferred pathways and triggers. (5) Implement the plan. (6) Monitor (Haasnoot, et al. 2013; Deltares, n.d. 1b). Step *2* should be reevaluated after finishing step *3* and the actions from step *5* should be monitored and evaluated during step *6*. If the process does not lead to desirable outcomes, or if new issues occur, step 1 can be reassessed.

In a Dynamic Adaptive Policy Pathways model measures working against a phenomenon are mapped out on the y-axis. Uncertainty regarding the phenomenon is mapped out on the x-axis, often represented in the extend that the phenomenon can occur. Measures are plotted from the left to the right. These measures have both a starting point, and an end point. The starting point is the extend of the phenomenon at hand, where implementing a specific measure will have an effect that aligns with the objective of the planner. The end point of a measure in a DAPP model means that the ability of this measure to change the subject of planning, is no longer sufficient. The endpoint of a measure is referred to as a Tipping point. If and when tipping points are reached, alternative adaptive strategies are required (Gladwell, 2000; Lindsay & Zhang, 2005 ; Russill & Nyssa, 2009 ; Kwadijk, et al. 2010 ; Haasnoot et al. 2013). Zandvoort et al. (2019), developed a model, Figure 4, showing adaptation and mitigating measures regarding sea level rise in relation to the extend of sea level rise.

Figure 4 shows that rising seawalls and bulkheads is a possible measure at 23 centimetres sea level rise, however, it would not be beneficial at 53 centimetres sea level rise. This means that a tipping point has been reached. In Figure 4, these tipping points are visually represented by a vertical stripe with Adaptation Tipping Point of an Action' in the legenda. Stepping away from our first measure, towards another measure is necessary to ensure that the Netherlands is protected from floods. Between scenarios there could also be a 'Transfer station to new action'. Here extra measures can be implemented or even combined. If the combination of measures is mapped out, planners can pick and follow one of the lines from the graph (Zandvoort et. a., 2019). Figure 4 shows how these measures are plotted to the uncertainty. When all measures are added to the graph, a desired route can be selected. If unexpected impact events occur, planners can use the graph as a framework and see where the consequences and potential high impact events fit in the route. This might mean that the route needs to change (Haasnoot et al. 2013; Zandvoort et. a., 2019). Going back to Figure 4, we can see that ''Hard in-land infrastructure to increase storage on land'' becomes relevant only after 23 to 53 centimetre of sea level rise. After that ''Adding Dikes and/or terraced seawalls along coastline'' becomes relevant at 91cm. Combining the three measures creates an example of an adaptation pathway that can be formed on the base of Figure 4. Considering the objectives of a plan, the feasibility of implementing measures, due for example time or financial constraints, the most desired route can be selected. This pathway can be followed by planners as a roadmap (Haasnoot et al. 2013). If unexpected impact events occur, planners can use the graph as a framework and see where the consequences and potential high impact events fit in the route. This might mean that the route needs to change (Haasnoot et al. 2013; Zandvoort et. a., 2019).

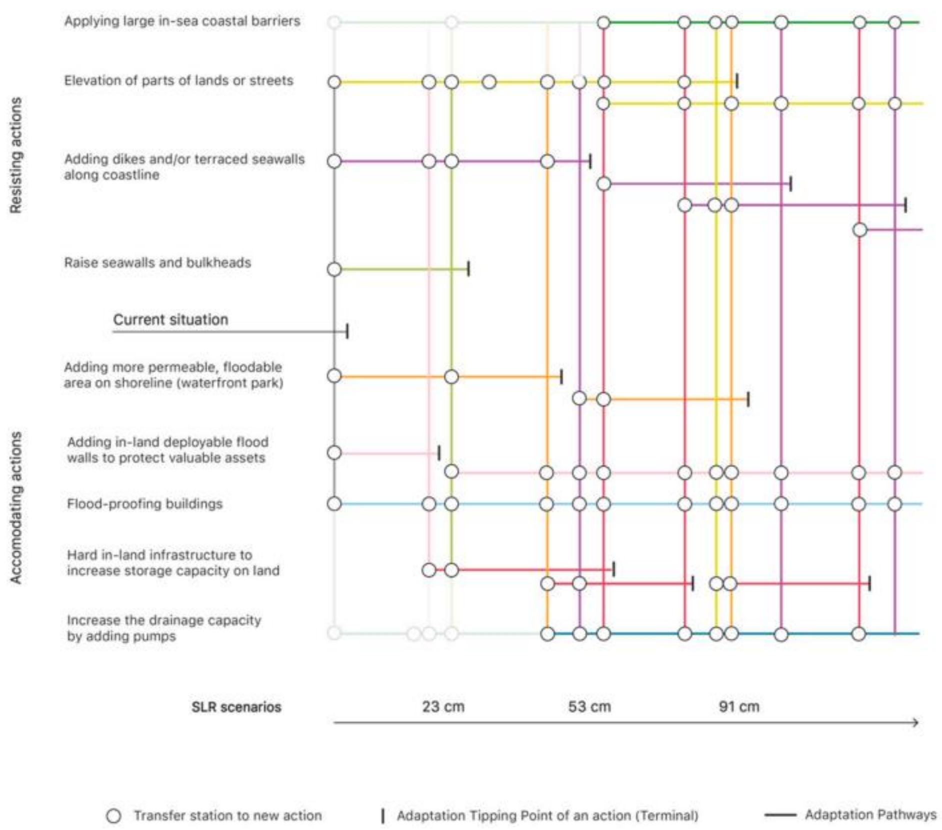
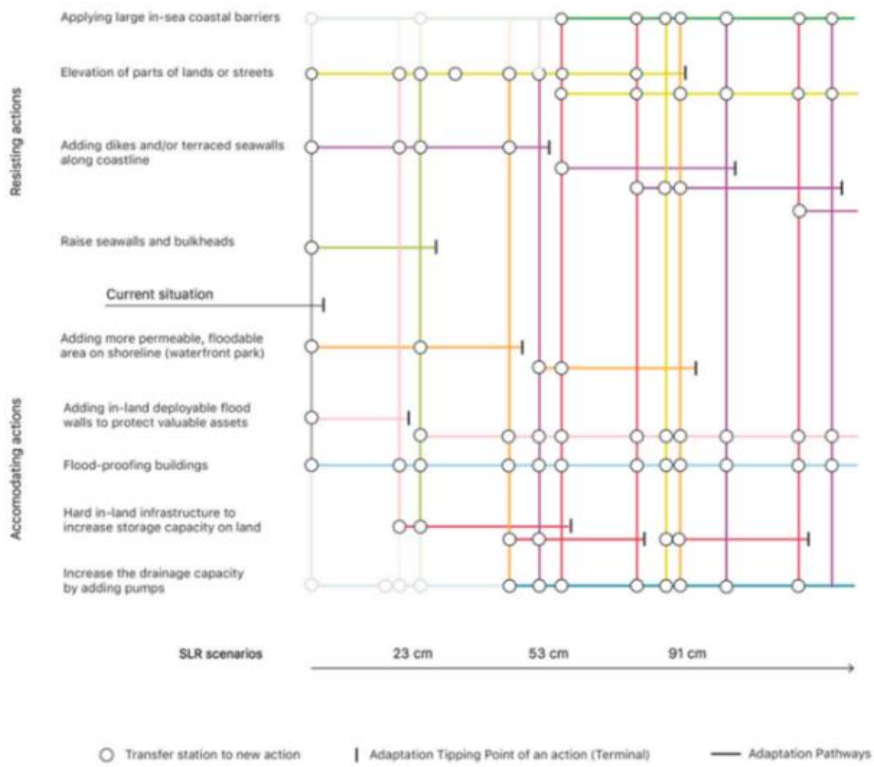
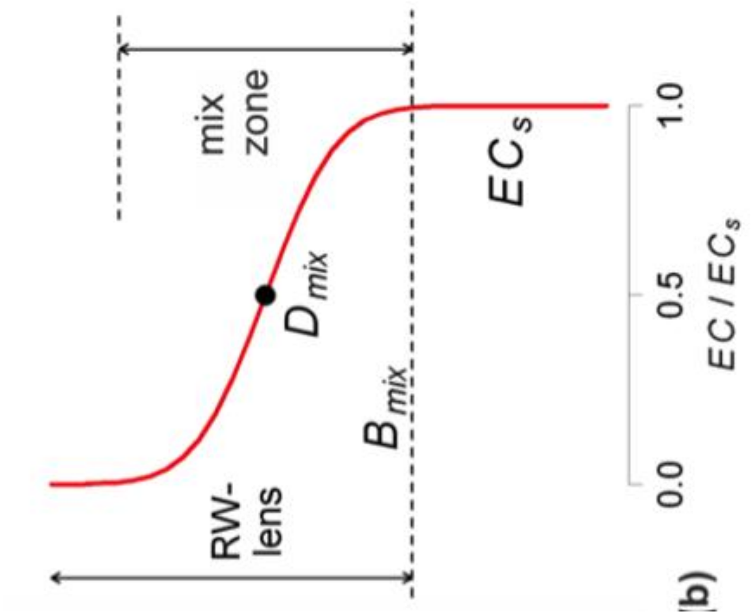


Figure 4 Example of a Dynamic Adaptive Policy Pathways model from Zandvoort et. al., 2019 p14

Dynamic Adaptive Policy Pathway approaches have been implemented in water management for a while (Deltares, 1a) but not yet for solving the salinization problem. In the Netherlands, planners have implemented DAPP for the Adaptive Delta Management approach (Deltares 1b), and to create a better understanding of coastal adaptation (Haasnoot, et al. 2020). The Dynamic Adaptive Policy Pathway approach has been helpful in aiding decision makers when making decisions when contexts are uncertain (Haasnoot, et al. 2009). In case of uncertainties DAPP's can be implemented to ensure that measures are not implemented to early or to late, by implementing a robust but open ended decision making path (Kwakkel et al. 2016). Dynamic Adaptive Policy Pathways are based on two approaches, Adaptive Policymaking and Adaptation Pathways. Adaptive Policymaking describes different types of actions, such as mitigation. In adaptive policymaking evaluation of measures is required.

Combining the findings from both salinization and the Dynamic Adaptive Policy Pathways approach would lead to the development of the DAPP model. The DAPP model by Zandvoort et a. (2019), as seen in Figure 4, is used as a visual guide to create the base for the model in this research. In this example different variations of sea level rise were used to express differences between tipping points between measures. For salinization sea level rise is a factor that plays a role in accelerating the process, however, it is not the main aspect of salinization. What is relevant is the depth at which the fresh water in the ground is replaced by brackish or even salt water. This can be found on the model of saline seepage from (STOWA, n.d 1b) as seen in Figure 1. By turning the saline seepage model on its side, the depth of salinization can be used as a guide to develop the tipping points, as seen in Figure 4. On that base a section of measures will be added, leading to Figure 4. Finaly the actors who must implement these measures are added to the model. Resulting in the final empty base model in Figure 5. The DAPP model will be filled in the result section with the specific tipping points, identified from the interviews.

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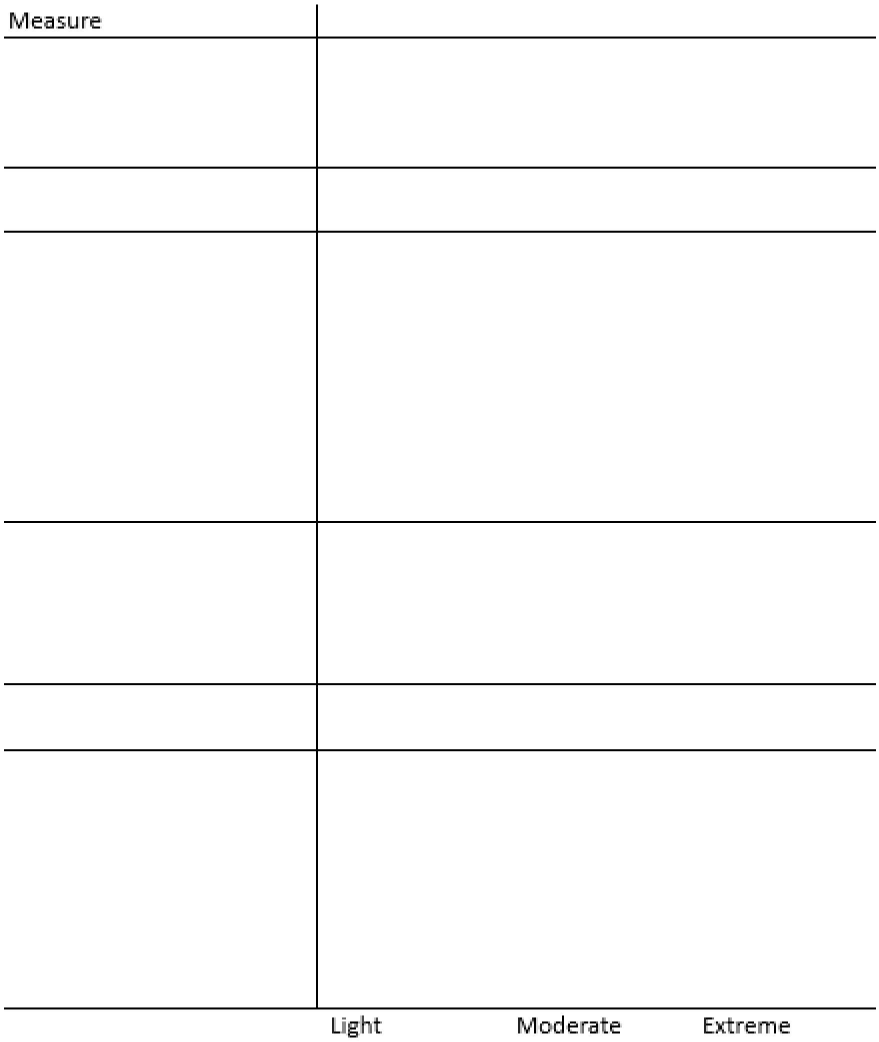

Figure 5 Base model and Measures, own source

The first aspect of filling in the base of the Dynamic Adaptive Policy Pathways model is to identify the tipping points. The tipping points are expressed as the extends of salinization at the bottom of Figure 4. The measures in the model from Haasnoot (2013) and Zandvoort (2019) are divided into two categories, adaptive and mitigating measures. For salinisation these measures overlap a lot, a distinct categorisation between adaptive and mitigating measures would not be relevant in this case as the bigger question is who is responsible for implementation. What is relevant however, is that measures taken for salinization all occur at different levels of government or even outside of governmental control. This is due to the issue involving numerous stakeholders and that it can be solved both by the individual owner of a plot of land and a collective approach by a governmental organization. This distinction will be represented on the Y-axis, as represented in Figure 5. In the result section, the actors will be identified and added to the conceptual model Figure 6.

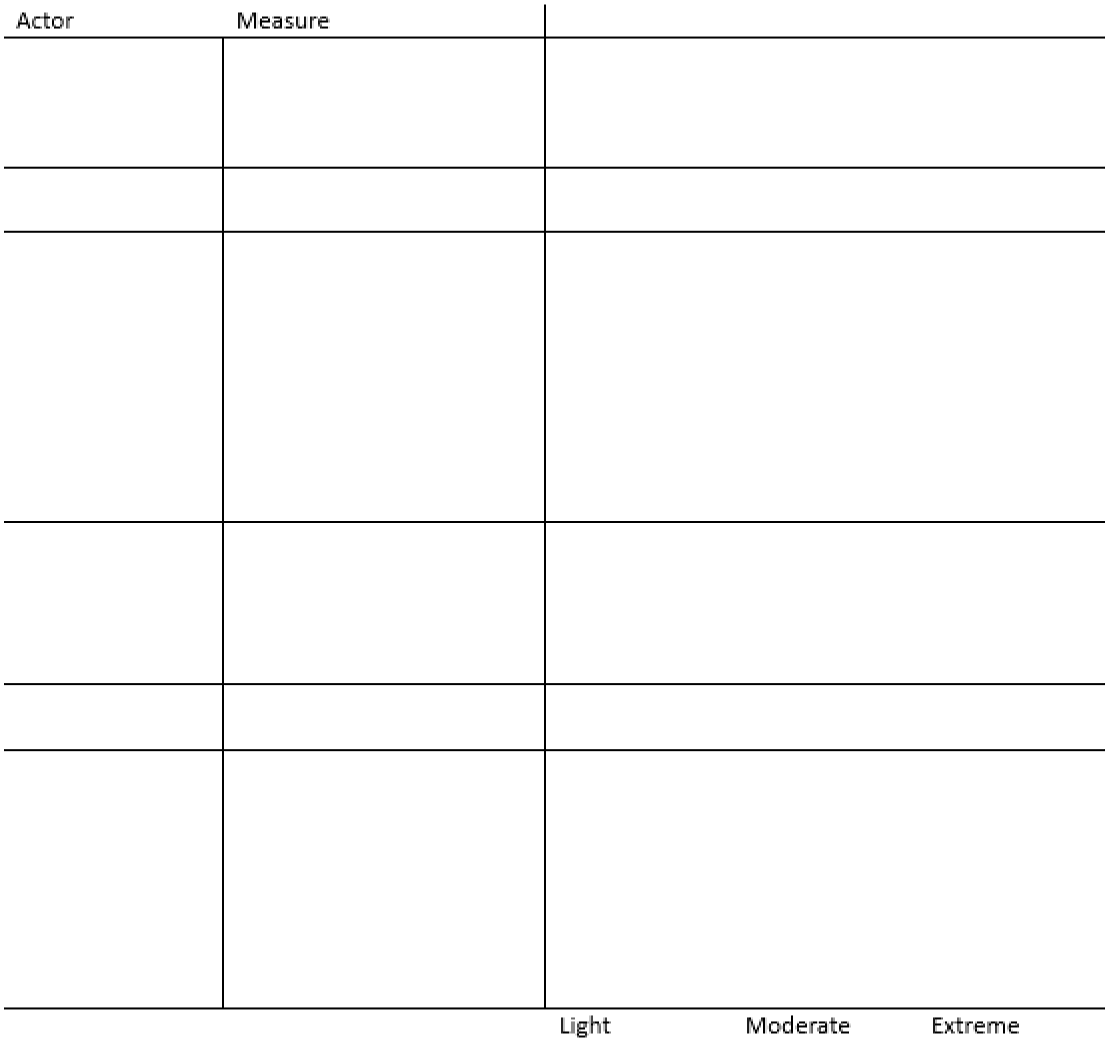

Figure 6 Base, measures and actors, own source

The Dynamic Adaptive Policy Pathways approach seems a promising planning approach when it comes to planning with uncertainty and climate change related issues. The approach is based on discussions with stakeholders and experts and evaluation after implementation. After stakeholders and experts together identify potential measures and tipping points a DAPP model can be developed. The DAPP model based on Zandvoort et. al., (2019) has measures divided between adaptive and mitigating measures, however, responsible actors are not mentioned in the model itself. In drought management three levels of government are responsible. Salinization is linked to drought, therefore it can be assumed that at least some measures against salinization fall under the responsibility of governmental bodies regarding drought management. Therefore, adding the actor responsible for implementation to the model is beneficial in the case of salinization.

3. Methodology and Research strategy

To answer the question ‘’ ’What is the potential of the Dynamic Adaptive Policy Pathways approach to aid planners in preventing the negative outcomes of Salinization in the north of the Netherlands?” mixed methods were implemented. Exploratory conversations and research shed a light on the differing availability of academic research on both topics. Creating an understanding of the concept of salinization through academic research is possible, however, the specific issues that Dutch planners face with salinization on Dutch soils is not represented in academic research. Whilst Dynamic Adaptive Policy Pathways approach is first introduced in the Dutch context and most, if not all, research surrounding DAPP’s have been in the Dutch context. This requires a different research strategy to thoroughly understand both Salinization and DAPP. Resulting in a separation of the research of both concepts, figure 7. For both concepts academic literature was implemented. Salinization required additional grey literature, as little information was available on the specific Dutch context. The literature review shed a light on gaps in the academic knowledge that this research aimed to fill. These gaps were converted into questions that were asked to experts in one-on-one semi structured interviews, appendix A. In addition to filling knowledge gaps, the interviews aimed to identify implementable measures that work against salinization and gain insight into how planners experience the current planning dynamic in regard to salinization. The results of these interviews were analysed in both a qualitative and quantitative method to ensure that as much information as possible was taken into account.

Figure 7 provides a visual overview of the overarching structure within the research design to explain the ways in which gathered data has shaped the course of this research and the eventual results that sparked from it. The research strategy started with exploratory conversations and data gathering. Based on this information and the gap in academic knowledge a research question was formulated. To answer this question, it is required to understand the concepts, ‘’what’’ in Figure 7, and how these concepts relate to each other, how in Figure 7. In order to get a specialized understanding of the concepts used within this research, academic literature was used to further understand the DAPP. Both grey literature as well as academic literature were used to formulate an overview of the available literature on salinization. This left some gaps of knowledge that required additional information. The gaps of knowledge, exploratory conversations, as well as the various types of literature relevant to this research were the building blocks that helped form the questions that were asked in the interviews with stakeholders and field experts. These interviews were implemented to further understand the concept of salinization, ‘what’ Figure 7, and to create an understanding of how these concepts relate to each other, ‘how’ Figure 7. Eventually leading to the DAPP model represented in chapter 4, Figure 8.

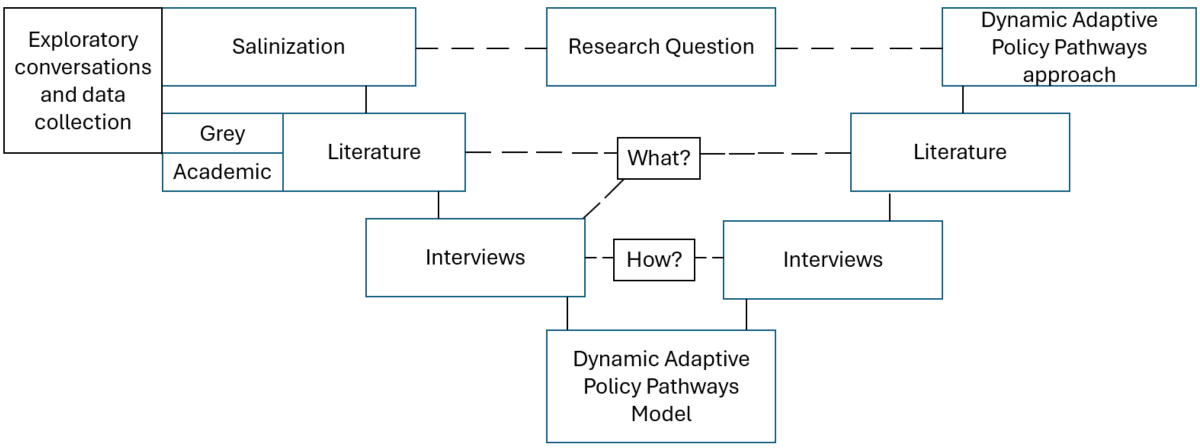

Figure 7 Research design, made by the author

3.1 RESEARCH STRATEGY FOR DYNAMIC ADAPTIVE POLICY PATHWAYS.

For the Dynamic Adaptive Policy Pathways approach academic literature was available for the Dutch context. The DAPP required a critical reflection on the manner of implementation. In academic literature DAPP is referred to as an approach, a tool or a concept. What a Dynamic Adaptive Policy Pathways is, or is not, has an impact on implement ability and should therefore be considered. This could be done through reviewing academic literature. During the interview stage of this research, the implementation of DAPP regarding Salinization was researched. The main question that required answering during the interviews for DAPP was, why would Salinization require the DAPP approach to solve the issue and why is salinization a suitable phenomenon for a DAPP approach.

3.2 RESEARCH STRATEGY FOR SALINIZATION

For salinization the research process started with exploratory conversations with experts in the field. This brought to light that there are several factors that increase the prevalence or the severity of salinization. In dry, desert like regions, salinization can occur through irrigation. This is not the case for the Netherlands, but it does entail the large majority of the academic research. In addition to this, salinization has a different impact depending on soil type. Sandy soils are less vulnerable to long-term negative effects of salinization which, again, is covered by the majority of available academic literature. To understand the impact salinization has on a Delta region, with a combination of sandy and clay soils information would be gathered outside of the literature review. Therefore, the literature review was supplemented with grey literature in the form of reports and internet research from reputable sources. These sources would be either governmental sources, private research institutions or government backed research institutions, which had experience with research and salinization, an overview of the reports consulted can be found in table 2. The majority of the reports and websites that have been consulted come from STOWA (n.d. 1a), as they have vast amounts of water related questions, answered on their website. Governments can contact STOWA for water related questions. STOWA then researches the topic. All results from this research are published online and are accessible to the general public and other governments to facilitate information to all actors requiring it. Information found on websites or in reports outside of these categories are verified by either information from more reliable written sources or verified through discussions with salinization experts. Discussion with salinization experts started with exploratory conversations, through email, telephone and face to face conversations. These exploratory conversations aided in creating a scope for this research and finding gaps in literature. All this information was used as the base for in depth interviews with salinization experts. Which in turn is used to develop a Dynamic Adaptive Policy Pathway model.

Source	Name	Implemented in the research process for,
Informatiepunt leefomgeving	Verdringingsreeks: rangorde bij waterschaarste	Deepening the understanding of measures against salinization
STOWA, Deltafacts	Bodemvocht gestuurd beregenen	Orientation on measures
	Brakke kwel	Deepen understanding before conducting interviews
	Dynamisch peilbeheer	Deepen understanding after conducting interviews
	Effecten klimaatverandering op landbouw	Deepen understanding before conducting interviews

	Ondergrondse waterberging	Deepen understanding after conducting interviews
	Regelbare drainage	Deepen understanding after conducting interviews
	Regenwaterlenzen	Deepen understanding before conducting interviews
	Water en Ruimtelijke Ordening: instrumenten voor betere afstemming	Deepen understanding before conducting interviews
	Zoetwatervoorziening	Deepen understanding before conducting interviews
	Zoetwater zelfvoorzienendheid van de landbouw	Deepen understanding before conducting interviews
	Zoutindringing	Deepen understanding before conducting interviews
	Zouttolerantie van teelten	Deepen understanding before conducting interviews
Klimaatinfo	Het klimaat van Nederland	Deepen understanding of the Dutch climate context.
KNMI	Jaar 2023	Deepen understanding of the Dutch climate context.
KNMI	Jaar 2022	Deepen understanding of the Dutch climate context.
Rijksoverheid	Deltaprogramma 2019	Deepen understanding before conducting interviews
	Deltaprogramma 2020	Deepen understanding before conducting interviews
	Deltaprogramma 2021	Deepen understanding before conducting interviews
	Deltaprogramma 2022	Deepen understanding before conducting interviews
	Deltaprogramma 2023	Deepen understanding before conducting interviews
	Deltaprogramma 2024	Deepen understanding before conducting interviews

Table 2 Grey literature overview

3.3 EXPERT INTERVIEWS

The last step of the empirical research entails interviews with eight different stakeholders. An overview of the interviewees is provided in table 3. The majority of the interviewees asked to remain anonymous, therefore the names of the interviewees are not mentioned, instead a general description of the employer of the interviewee is provided. Comparable studies have implemented data collection through on sight observations, case studies, desk research or interviews with professionals (Lieftink, 2021). This desk research, however, has a more general focus, therefore a case study would be too specific. In qualitative research (expert) interviews are widely implemented for gathering information and creating a better understanding of the social reality (Döringer, 2021). During these interviews the perspectives and the experiences are seen as just as important, or more important than quantifiable knowledge (Döringer, 2021). Interviews can have various forms, one-on-one interviews, group interviews and they can vary from being completely open to completely structured. For this research one-on-one interviews were chosen as they allow the interviewee to provide as much information as possible, without being interrupted by other interviewees. They would also be able to speak freely as they were informed beforehand that the interviews would be analysed anonymously. Group dynamics or quotes from interviewees with their names attached to them, could ensure that interviewees would not feel comfortable sharing experiences. The semi-structured interview a form of the expert interview where preconstructed questions are implemented to guide the interviewer and the interviewee through the interview (Shoozan & Mohamad, 2024). If necessary, the interviewee has the opportunity to elaborate more on topics they see as important. The interviewer has the opportunity to ask more in-depth questions when they feel like there is more information available. The interview guide was developed based on the gaps in the literature and can be found in Appendix A. To ensure that there was enough time for the interviewee to answer all the questions, specific workings of measures were not explained in the interview but researched at a later stage. The interviews were in between 30 to 45 minutes to ensure for enough time for elaboration, but concise answers that would still be able to be analysed. Possible interviewees were identified through multiple approaches. The salinization experts were identified through internet research for institutions researching salinization or saline agriculture. One salinization expert was found in the personal circle of the author but did also come back in this research. After each interview the interviewee was asked if they knew other organisations or researchers that needed to be interviewed as well. All these actors were contacted as well. A few salinization experts did not have the time for interviews but would be open to answering questions through email. These experts were not asked interview questions, to ensure that the data collection method remained consistent. For the governance aspect of the research, a geographical search was conducted for governmental organizations in the North of the Netherlands who are affected by salinization. These organizations were emailed with the question if they were available for interviews. Municipalities replied that they did not have the time for interviews. Other governmental organizations were willing to participate in this research.

Interview	Background	Expertise
1	Research institution	Salinization
2	Research institution	Salinization and governmental implications
3	Province of Groningen	Climate adaptation
4	Farmer in the North of the Netherlands	Saline cultivation
5	Province in the North of the Netherlands	Salinization and governmental implications
6	Waterboard in the North of the Netherlands	Salinization and governmental implications
7	Rijkswaterstaat	Salinization and governmental implications
8	Research institution	Dynamic Adaptive Policy Pathways and salinization.

Table 3 Interviewee overview

3.4 ANALYSIS

The interviews were transcribed to allow for in depth analysation. The transcripts were analysed both in a quantitative and a qualitative method. If one interview provided interesting or new perspectives, the next interviewee would be asked their perspective about it. This cannot be seen as a discussion between interviewees, as the first interviewee did not have the opportunity to provide context based on the response of the next interviewee. Some of the questions surrounding salinization were quantifiable, the results have been put in a graph in the results chapter. Certain interview questions can be grouped together to show the general perspective of the experts on salinization. How big the issue of salinization is and who is responsible for solving it. Measures against salinization were also identified, in addition to an overview of the measures being seen as positive or negative. Measures are explained one by one based on information from the interview, supplemented with grey literature. Then the measures are put in a graph to provide an overview with all benefits, drawbacks, tipping points and actors responsible for implementation.

3.5 ETHICAL CONSIDERATIONS

Ethical considerations surrounding privacy of the interviewee was a complicated situation. Most interviewees requested to remain anonymous. However, to analyse the interviews recording was required. Transparency regarding the identity or the profession of the interviewee would make the research more replicable, and it can help understand the perspective of the interviewee, however, knowing that the name of the interviewer can be linked to specific statements could hinder the interviewee in speaking freely. Considering the current political sensitivity surrounding the relation between governments and farmers, in this research transparency was seen as less of a priority than privacy. Additionally, the interviews were mainly conducted digitally. Both aspects can be susceptible to hacking. Therefore, a secure browser was used by the interviewer. The audio-recordings are stored on a password protected computer. The audio-recordings would only be shared with the thesis supervisor and board of examination they explicitly request them. The recordings will be deleted when the process of the Master Thesis is finished. The interviewees were informed that the interview would be recorded at the beginning of the interview. After they agreed the recording was started, then they were asked the same question again to ensure that the interviewer followed the proper procedures, the General Data Protection Regulation, implemented by the University of Groningen and the European Union to ensure that research is conducted ethically. This entailed both informed consent from the interviewee and data collection privacy (GDPR in Research, 2013).

4. Results

In this chapter the results of the empirical study are represented. Firstly, the answers of three of the general interview questions can be put in a table where interviewees would fall in one of three categories, Table 2. The categories represent the extend they see salinization as a problem and the extend of which they see governments as responsible for solving the problem. One interviewer did not feel like they were qualified enough to answer the specific salinization questions, as they were more familiar with governmental tools and less familiar with specific knowledge on salinization, resulting in seven respondents for this table. They were able to answer the last question, therefore they were taken into account in these questions.

4.1 GENERAL PERSPECTIVES OF THE INTERVIEWEE

Question			
1. Is salinization a problem that requires planning intervention by government?	Salinization requires full governmental control.	Salinization requires collaboration between private owners and government.	Salinization should not be dealt with at a governmental level at all.
	0/7	**5/7**	2/7
2. What is the biggest problem with salinisation	We do not know what exactly the impact will be, but based on our estimations it will have negative effects if there is no governmental intervention	We do not know what exactly the impact will be, but based on our estimations it will manageable if we intervene when the problem becomes worse	We know exactly what to expect when salinization continues to occur, no further intervention is needed.
	2/7	**4/7**	1/7
3. Currently there are enough measures that can be implemented against salinization	Measures are non-existing OR financially not feasible. When more information is available more measures should be developed.	There are enough measures for now. When more information is available more measures should be developed.	We do not need more measures against salinization, we need to accept what is happening and change food production.
	2/7	**4/7**	1/7
4. I work at	A research institution	A governmental institution	An agricultural farm
	3/8	**4/8**	1/8

Table 2 Is salinization a problem and who is responsible?

One out of seven interviewees expressed that salinization is not an issue that requires solving and thinks that salinization is a process that planners need to learn to live with. The other six out of seven interviewees agree that something has to be done to stop the phenomenon of salinization. None of the interviewees see the government as the only actor responsible for solving the issue of salinization, five out of seven interviewees favour a combination between governments and private actors to work together on specific and local implementation. Two interviewees did not see the government as responsible for solving the issue at all. Five out of seven of the interviewees agree that salinization does require a planning intervention, however, they do say that interventions should be a combined effort between the landowner and the government (Figure 2). This could have multiple reasons. Salinization prevention measures are expensive (Interview 1, 2, 5, 8) and farmers are most likely to only take action when either the cost of salinization becomes very high (interview 1) or governments provide subsidies for implementation (interview 5).

The interviewees also provided an indication on if there are sufficient measures available that can be implemented. Most interviewees expressed that there are sufficient measures for now, but development of new measures in the future would be beneficial. It is important to consider that the three interviewees most familiar with the costs of these measures either expressed that the costs of implementation are too high for most farmers, or they own a farm that has a focus on saline cultivation and therefore measures are not applicable in this case.

4.2 MEASURES IDENTIFIED

Measure	How often mentioned	Positive remarks	Negative remarks
Anti-salinization drainage	5	**5**	0
Bubble screen	1	**1**	0
Closed system agriculture	3	1	**2**
Freshwater buffer	7	**7**	0
Extract saline water from the ground	1	0	**1**
Flushing soils	5	1	**4**
Irrigation ban	2	1	1
ASR	3	1	**2**
Saline cultivation	2	1	1
More research	7	**7**	0

Table 3 Measures identified

In Table the measures proposed during the interviews are represented. The number of different interviews the measure was mentioned in was counted, and it was noted if this mention was positive or negative. A positive was counted when the interviewee described the measure as financially feasible or if the impact of the measure being sufficient. A negative was counted when the measure would be near impossible to implement, or if implementation costs were high, relative to other measures. In the Discussion the argumentation behind these distinctions will be further explained. It is interesting to see that all interviewees agreed that more research was needed to fully understand salinization and the impact it will have on soils and crops. However, the research approach was a point of discussion between the interviewees. Maintaining the freshwater buffer came out as the most mentioned measure. It was described as positive and feasible by all interviewees. With anti-salinization drainage being the most mentioned measure to ensure the maintenance and water quality of the freshwater buffer.

Now, that we have an understanding of the perspectives on salinization and the measures that can be implemented, we need to take a look at the results regarding the Dynamic Adaptive Policy Pathways approach.

For this part of the interview, interviewers were asked if they experienced any shortcomings in tools and resources regarding planning for climate related issues or salinization specifically. One of the interviewees described that they, the institution not the individual, were looking for an approach that would provide them with structure and perspective but would leave them with the flexibility to change if the situation demands it. The interviewer metaphorically described their desired framework-tool as a menu to structure all other tools and specific measures. Tools in a toolbox are unstructured and require a new approach each time, but with a menu the user knows to start with an appetiser, then the main course and finishes up with desert. For example, tiramisu is not served as an appetiser, providing the user with a structure, or context, for when what option can be chosen. Providing some structure, but still dynamic and adaptable enough to fit into specific scenarios. Adaptation approaches are not written in stone and if all actors gathered at the dining table together decide that today is desert day, Tiramisu can be served as an appetiser, main course or only eaten as a desert. Providing planners with a flexibility that can be implemented when the context requires this flexibility.

Other stakeholders expressed that there are a lot of gaps in the knowledge and a lot of measures that can be implemented. But there is no set overview. Having such an overview would aid them in understanding the problem at hand and communicating about this problem with other stakeholders. If the Dynamic Adaptive Policy Pathways approach is the only approach that would be able to do this, seems unlikely.

5. Discussion

In this chapter, the results of the interviews are supplemented with theoretical information and the responses of interviewees are compared to each other. The measures are explained one by one. If possible, drawbacks, benefits and tipping points are identified. Finally, a Dynamic Adaptive Policy Pathways model is developed. Possible pathways are identified

5.1 MEASURES

Solutions regarding salinization, and therefore also droughts, mainly focus on maintaining the freshwater buffer in the soil, Table . Maintaining a freshwater buffer in the top layer of soil allows plants to grow in non-saline conditions (interview 1, 2). During the winter, heavy rainfalls make fresh water available (Interview 1, 6, KNMI). It takes time for water to infiltrate in the soil. Too much water on soils hinders famers ability to enter their fields with big machinery. In the autumn, spring and summer farmers need access to their lands for sowing, harvesting, fertilization and other crop specific activities. During these periods, water is purposefully drained off, to ensure access to these fields. During winter, farmers usually do not enter their fields with heavy equipment (interview 1). Providing the time for water to naturally infiltrate in the ground. However, typically the drainage systems that are in place to drain the water during the spring, summer and autumn are present in the soil. Implementing approaches to limit output through drainage systems allows the water to infiltrate through the soil. This can be implemented through simple drainage systems such as an Ebb and Flow drainage system (Understanding the Ebb & Flow System, 2024) that allows water to flow out of the system when plenty is available, but can be closed when retention is desired. Or by implementing drainage systems specifically developed as anti-salinization drainage systems (Anti-verziltingsdrainage, 2021). Lastly, technical drainage systems can be implemented.

Traditional forms of drainage have drainage points close to the surface (Anti-verziltingsdrainag, 2021). Due to the speed of drainage, the freshwater buffer is not able to replenish itself in times of high precipitation, consequently increasing the speed of upwards seepage. Lowering the intake of drainage points, increases the chance of draining salt water, leaving more room above the saltwater table for fresh water. This type of drainage system is referred to as anti-salinization drainage system (interview 1, 2, 5, 6 and 8). The lowered intake of drainage points can be implemented as a stand-alone option, however, most anti-salinization drainage systems implement a closed water buffer as well. This water buffer can extract water on both mean water level, or it can have the ability to pump more water into the buffer, increasing the amount of freshwater available in summer. Therefore, not only counteracting the negative impact of salinization, but also the negative impact of drought. The specific combination of capacity of the buffer and the depth of drainage intake points is dependent on the implementation context. Permeability of the soil, current size of the buffer and the extend of salinization all impact the most ideal type of drainage (2021). Anti salinization drainage systems have been researched at different locations in the Netherlands, on both clay and sandy soils (Tolk & Velstra, 2016). The locations have been thoroughly researched beforehand, to create an understanding of water flow in the soil, the level of saline seepage and the quality of the soil. Based on these, and many more characteristics of the soil, the type of drainage system was chosen. This researched showed that implementing the right type of drainage system can halt the process of salinization, and slightly reverse the process by increasing the freshwater buffer. Effects are bigger when drainage points are implemented lower in the ground. The reversal process starts within a couple of years and is most effective on clay soils (2021), which is promising as most reversal measures do not work on clay soils. Anti salinization drainage systems also provide positive externalities. The first being the reduction of outflow of nutrients toward surface water, increasing the quality of surface water in the Netherlands.

Secondly, reducing the general output of drainage systems, therefore reducing the amount of water needed to be pumped out of the Netherlands to the North Sea during times of increased precipitation. Implementing anti-salinization drainage systems cost about the times as much for the farmer than traditional drainage systems. This goes for both implementation and yearly maintenance (2021). As for now the farmer is solely responsible for the implementation. An investment in this system is only beneficial if risk of damage to highly profitable saline sensitive crops become to high. On the other hand, anti-salinization systems are much cheaper than other identified measures, such as ASR (Interview 1, 2 and 5). Considering the externalities of anti salinization drainage systems, governments might find it beneficial to provide subsidies or other forms of aid for implementation of anti salinization drainage systems. The Wadden region of the Netherlands is the most promising area for implementation of anti salinization drainage systems. If it would work outside of this region has not been sufficiently studied yet. It is also currently unknown, to what extent of salinization anti salinization drainage systems would work.

Besides natural replenishment and anti salinization drainage systems, technical systems of water retention can be implemented as well. Aquifer Storage and Recovery systems (ASR-systems) work by injecting fresh water into underground wells or aquifers, this water can be recovered at a later stage for consumption. This technique allows users to store large amounts of water, with a reduced risk of contamination. However, ASR-systems are expensive (interview 1, 5), therefore they are only implemented when the crop type is profitable enough to offset the investment in technical drainage systems (Interview 5; Zuurbier et. al., 2014; Deltafacts). Considering that there are other, less expensive options, private landowners might be less inclined to implement ASR-systems, compared to anti salinization drainage systems. ASR-systems provide the user with the ability to use the recovered water with the same quality as it was pumped into the aquifer. Therefore, this type of measure, might be more appropriate for implementations where quality of water is important. Considering the costs of this measure, large scale implications reduce the cost per litre water. Moving the theoretical most fitting user to institutions with more financial capabilities.

If large scale measures are required, the basic concept of the anti-salinization drainage systems can be implemented on a larger scale. Saltwater extraction is a large scale technical measure that could be implemented in the future. Due to the cost of researching on a larger scale, no research has been done. Anti-salinization drainage systems work by draining salt water deep in the soil. This concept can be implemented on a large scale as well. At one central point, or a few central points, vertical pipes could be put in the ground. Through these pipes salt water could be pumped out of the groundwater. Reducing the height of saline seepage and creating more space for a freshwater buffer (Interview 5). As this approach is not tested yet, we do not know if it will work in practice. For general Anti-salinization drainage systems, the results of the system depend on the soil type and the permeability of the soil. It can be expected that the same goes for large scale saltwater extraction. As it is currently not implemented, the development costs of this measure are expected to be high. Therefore, it should not be implemented at light to moderate stages of salinization.

Salinization can come through groundwater being pushed from the sea to the surface, but it can also occur as water from the sea flowing land inwards through the rivers. Due to salt water being heavier than fresh water, a salt tongue (Verzilting – Oorzaken, Gevolgen En Maatregelen, 2024), is able to intrude far backwards into the land. This causes risk, when the salt tongue arrives at inlet locations for drinking water or irrigation (Interview 7). When sufficient water is available, increasing the outflow of freshwater pushes the salt tongue back to the sea. When there are not enough water available, technical implementations are required. This can be done through closing the rivers off from the sea through dikes, dams and other waterfront protection measures. However, this comes with limitations as well. It removes the possibility of migrating fish to enter the brackish waters of the river delta. It also reduces the opportunity for ships to freely travel further inland. Even with the implementation of sluices a prominent salt tongue can be formed (2020). Fully blocking the entrance to the rivers is not necessary to prevent a salt tongue of entering too far inland. Disrupting the flow of the salt tongue can be implemented through other measures. One of such measures is a bubble screen. On the base of the river, a tube with little holes is placed. Air is pushed through the tube (2020). This air comes up to the surface in bubbles. These bubbles disrupt the salt tongue. Allowing the salt water to move towards the surface and being pushed back into the sea, without increasing freshwater flow.

During the interviews it came to light that a lot of farmers do not see salinization as a risk for crop growth (Interview 4, 5). ''As a province we have been trying to find farmers who express that salinization is an issue, this has been difficult'' (Interview 5). This can have various causes. Firstly, salinization damages to crops, mainly coexist with drought damages to crops, therefore salinization does not present a stand-alone risk for profits. Reducing the desire for adaptive or mitigating measures. Secondly, Crops that are less sensitive to salinization are becoming less profitable, therefore farmers are choosing to move away from less sensitive crops towards more saline sensitive crops (Interview 6). The waterboard, is affected by the crop choice of the farmers. An example would be Oldambt, a North-Eastern municipality within the province of Groningen, traditionally farmers would manly cultivate grain, even to the extent that it inspired a local identity surrounding grain (https://www.visitgroningen.nl/nl/plekken/oldambt/de-graanrepubliek). Grain is a crop that is not very sensitive to droughts during the summer months, it can be harvested relatively early in the growing season (interview 6). Nowadays farmers are shifting away from the production of grain, towards a production of peas or potatoes. These crops require more water during the dry months of July and August. Increasing the demand for freshwater, during a time when it is limitedly available. Waterboards and other layers of government are unable to ban the cultivation of water intensive crops, in favour of more robust crop types. However, it is clear that an increase in demand for freshwater, during a decrease in supply of freshwater is not a sustainable approach in the long term (interview 6). Even though there is potential in saline cultivation (Interview 4), traditional forms of agriculture still require the availability of freshwater. Dutch water management has facilitated farmers with the right conditions for agriculture. This gave farmers the idea that presented issues will not be an issue for them (Interview 5, 6). All in all, the long term risk of salinization is not known by farmers. Therefore providing information surrounding the long term risk of salinization to farmers and information surrounding potential measures is critical in increasing the implementation of increased investment that will make a return in the long term, not just for the short term (2021). As of now, governments are not able to ban certain crop types based on their water requirements (interview 6), however informing farmers about the implications and risks of their crop choice is allowed. There is no governing body that implements this in their information campaign or contact with farming associations (interview 6). However, this might be a low-impact measure that could be implemented in a relatively short term.

Communication with farmers regarding salinization can aim to promote mitigation measures, but it could also be a tool to provide information surrounding adaptation measures. If salinization occurs to the extent that traditional farming is not possible anymore, the farmer might decide to move away from traditional crops to saline cultivation. Various trail farms in the Netherlands are already experimenting with crop production under saline conditions. The most successful trail farms are not only experimenting with what crop type is able to grow under saline conditions, but also what sub-type fits the function best (Interview 4). If a potato is produced for food, it has to taste good. When hemp is produced for fibre, it needs to be strong. In various farms in the Netherlands, farmers are combining the aim to reach the highest quality possible, regardless of salinization or other matters impacting soil quality, with the end goal of producing ‘superfoods’ (interview 4) or super products. Not all of these trail farms receive financial support from governments or other parties. Therefore, they can also be used to create an understanding of the business case for farmers to implement these crops.

Not all farmers are open to saline cultivation (Interview 5), but that does not mean that they are optionless. If the phenomenon of salinization reaches a point at which soil and soil water conditions are unreversible salinized, closed system agriculture can become a requirement for farmers to continue their business. Closed system agriculture is a form of crop production where crops are grown in greenhouses, reducing the water loss through infiltration and evaporation. These systems require a lot less water and space than traditional systems (love, 2015). Which would mean that fresh water that would go to irrigation before the implementation of closed agriculture, now becomes available (interview 6). On the other hand, implementation of a greenhouse to save water is beneficial in very dry climates, but in the Netherlands too much fresh water is available at this point in time, for farmers to invest in these types of systems (interview 4). Implementing a greenhouse plus closed water system is expensive and due to low cost of fresh water is not economically feasible (interview 1). In addition to this, building a greenhouse is often dependent on a permit from local governments (interview 4). If governments are collaborating with farmers through a DAPP approach, this process can be sped up, for faster implementation.

The assumption from farmers that sufficient water is available for irrigation is not always true. Waterboards and Provinces are able to limit or ban irrigation based on the ‘’Verdingingsreeks’’ Table 1. Banning irrigation might lead to increased saline seepage on a plot of land (interview 6), however, it leaves fresh water available in diches (interview 7). Considering Figure 1, we know that saline water flows to these ditches. Draining them to irrigate plots of land, leaves less downwards pushing pressure to prevent saline seepage. Another downside to this measure is that it is not enforceable. Irrigation bans have been implemented before, however, if a farmer would irrigate during the night, it is very hard to see that this is going on. Proving transgression of this ban is hard and therefore this ban is barely enforceable in practice (Interview 6).

Flushing soils is one of the measures widely implemented on an international scale but is limited in its possibilities in the Netherlands. Flushing soils is promising on sandy soils when sufficient freshwater is available (Interview 1, 2, 6, 7, 8), it can be successfully implemented close to river salinization (interview 7), or close to the Ijsselmeer where freshwater is available in large amounts (interview 1). However, for the most part of the Netherlands flushing requires 1, an amount of water that is unleasable (1, 2, 6) or it would not work due to the soil type (interview 2).

All interviewees agree that more research is needed, Table . Many aspects of salinization are not sufficiently understood. This has various reasons. Some interviewees expressed that there are too little data gathering points to fully understand how saline seepage moves through the soil depth wise and how this impacts a plot of land (interview 2). If there are theories on how this process works, all research cites the same source (interview 1). This does not enhance the theoretical debate, and it could be that the case all research refers back to is an anomaly. We know that salinization is impacted by hydrological processes, but we often forget that other functions in the landscape have an impact as well. For example, deepening a riverbed to allow for larger vessels also allows for more river salinization to occur (interview 7), considering that river salinization is well researched and unavoidable if too little freshwater is available (interview 6), this can lead to even bigger problems. Further filling in this gap of knowledge would be beneficial, however many stakeholders do not have the capacity to only focus on the impact of salinization, leaving research regarding this issue on the backburner (interview 6). Additionally, stakeholders experience salinization relatively (interview 1, 4, 5). Where some farmers report issues with levels of salt concentrations that are normal to other farmers (interview 4, 5). We know that high salt concentrations can cause problems when they occur in the root zone (interview 1, 2) , but we do not know if there are long term negative outcomes if salt concentrations are high, just below the root zone (interview 1), although some research shows that clay soils become uncultivatable if salt concentrations are high, as minerals in the clay bond with sodium in the salt and harden the soil (interview 2). However, since this is not something that came back in every interview, it might not be common knowledge or hardening of the soil might not occur in every situation. If the latter is true, it would be valuable to know why it does or does not occur. Then we might be able to develop a new measure.

Interviewee 4 expressed that traditional forms of academic research do not benefit the practical nature of salinization. As sterile labs do not take into account the often-messy nature of a real life farm. On the other hand, is salinization often a consequence of drought. Researching the impact of salinization, without researching the impact of drought is impossible in practice. Therefore, some aspects of this phenomenon need to be researched in an environment that is void of external factors. It is quite strange that we do not know how big the problem is, as in the last 10 to 20 years large sums of public money are invested in prevention research (interview 5). We do not know how much salinization will cost us if we do nothing.

An interesting distinction between the risk assessment of stakeholders regarding salinization can be seen when we compare governments to government-funded research facilities. Two of the three interviewed governmental organizations do not see salinization as a big issue. It mainly comes down to the farmer being the risk bearer and the responsible party for implementing salinization. If large scale issues do arise, governmental bodies are willing to take action. However, at this point in time it is hard to find farmers that take the time to inform governments about their issues regarding salinization. It is important to consider that that farmers do not complain about issues regarding salinization, as it is hard to differentiate the impact of salinization from the impact of drought. The latter phenomenon is being complained about to governments. In addition to this, we have had two very wet years in 2023 and 2024 (Interview 2), which might lead to the reports being less recent in the minds of governmental employees. If we compare the stance of governments to research facilities that work with salinization, we see that these facilities do see salinization as a risk for future agricultural production. They see salinization as an issue that is not understood well enough to be discarded and advocate for it to be put higher on the list of priorities. With this perspective it is important to keep in mind that these research facilities are backed by governmental funding and therefore might be incentivized to exacerbate the problem. However, their stance does not necessarily mean that there is a financial bias, as it is also possible that working with salinization has led to a better understanding of the phenomenon, increasing urgency to finding solutions. Besides this, governments have various public interests that need to be considered. They might be able to see salinization as a big issue on itself, but compared to other issues, salinization might seem small. In addition to this, it could be that governments see salinization as a consequence of climate change and might be more inclined to implement holistic measures that either mitigate or adapt to climate change. Whilst for researchers only researching salinization, the phenomenon might be seen as a single issue. As this research aims to answer the question weather DAPP's can aid planners with dealing with salinization, and not to identify all potential biases in research or government, definitive conclusions cannot be drawn from this finding.

A negative outcome of this disagreement in perspective is that agenda setting on a governmental scale does aid lower governmental levels or individuals to make choices according to the plans of the government (interview 3). When higher levels of governments do not prioritise certain topics, or if they are not consistent with, they view of a topic, lower levels of government do not know how to address the issue (interview 3).

Measure	Start	End	Drawbacks	Positive	Actor
Bubble screen	Moderate	Extreme	Only works for river salinization.	It reduces negative outcomes further inland. Reduces amount of water needed for flushing. Low-cost implementation	Rijkswaterstaat
Freshwater buffer	Moderate	Extreme	Buffer is reduced in summer during droughts, requiring governmental support during moderate to extreme droughts.	Buffer will go back to the original size during wet seasons	Water boards
Extract saline water from the ground	Extreme		Expensive Cost for the collective, not just the farmer		Water boards
Flushing the soils	Low	Moderate	More effective in mild cases on sandy soils Requires large amounts of fresh water, which is often not feasible	Partly natural process as this already happens during wet seasons	Water boards
Irrigation ban	Moderate	Moderate	Increases salinisation Requires a shift in thinking from farmers to ensure that they either store water themselves or only grow crops that can deal with dry conditions	Implementing this earlier would reduce the need for it at a later stage where salinization is more extreme	Water boards
Extract saline water from the ground	Extreme		Very costly and not a proven measure		Province
Irrigation ban	Moderate	Moderate	Increases salinisation Requires a shift in thinking from farmers to ensure that they either store water	Implementing this earlier would reduce the need for it at a later stage where salinization is more extreme	Province

			themselves or only grow crops that can deal with dry conditions		
Communication	Low	Extreme	Large scale communication might be complicated due to local differences in the extend of salinization. For all extends of salinization a new communication approach is needed	It could aid in creating a mutually beneficial working relationship between the farmer and local government.	Municipality
Freshwater buffer	Low	Extreme	Buffer is reduced in summer during droughts	Buffer will go back to the original size during wet seasons	Private owner
Anti-Salinization drainage	Low	Extreme	Anti-salinization drainage is more expensive than traditional drainage systems	Anti-salinization drainage is cheaper than systems such as ASR and can have a slight reversing effect on salinization if implemented correctly	Private owner
ASR	Extreme		Costly Only economically feasible with Expensive crops	Pushes saline groundwater down	Private owner
Flushing the soils	Low	Moderate	More effective in mild cases on sandy soils Requires large amounts of fresh water	Partly natural process as this already happens during wet seasons	Private owner
Saline cultivation	Moderate		Communicative measure (not enforceable, only by choice of the farmer)	Requires an agricultural shift. Less profitable	Private owner
Research, General	Every		Costly process	DAPP model provides insight on specific knowledge gaps. These can be researched to reduce uncertainty.	Various levels of Government

Research Specific	Every			Each stage of salinization has its own implications. Measures should be researched at every stage.	Various levels of Government

Table 4 Measures, benefits, drawbacks and actors in a graph, own source

5.2 DYNAMIC ADAPTIVE POLICY PATHWAY MODEL FOR SALINIZATION

The measures identified during the interviews, Table 3, are supplemented with additional grey literature in the discussion. To provide an overview of the large body of text, the measures have been put into Table . Additional information, such as, when the measure can be implemented, tipping points, drawbacks or extra benefit and the actor responsible for implementation are added. This information can be used to fill in the base Dynamic Adaptive Policy Pathways model Figure 6, to reach Figure 7.

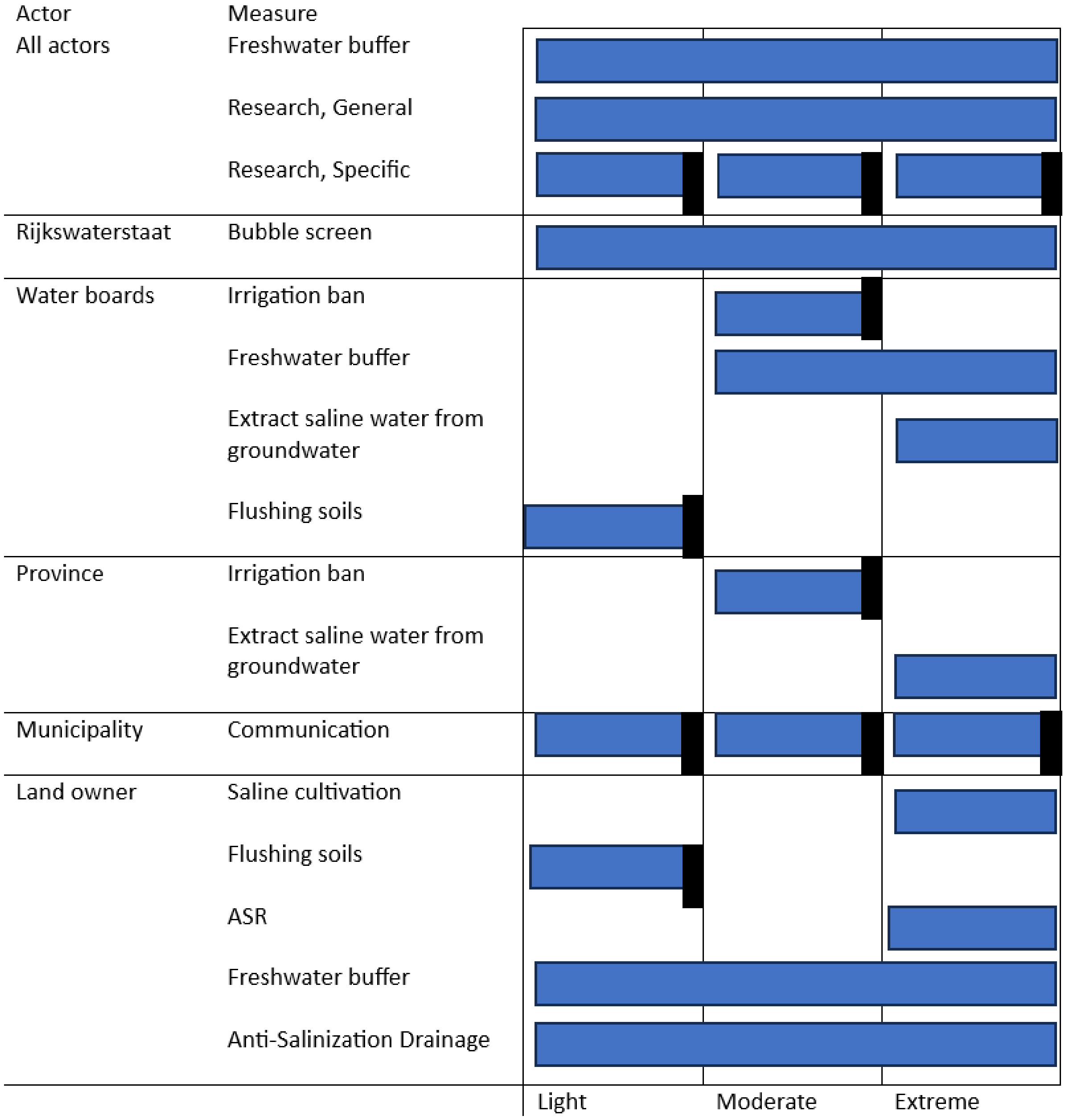

Figure 7 Dynamic Adaptive Policy Pathways Model

Looking at Figure 7, we see that the private landowner has the most measures at their disposal. However, this is also the actor with the least financial recourses. Providing subsidies for implementation of measures is not proposed as a necessity during the interviews, but it was briefly discussed as a potential incentive for landowners to implement more measures.

In a true Dynamic Adaptive Policy Pathways approach pathways are identified based on the DAPP model, Figure 8. To illustrate what adaptation pathways could look like on the base of the identified measures from the interviews, 6 examples of pathways have been put into the model, Figure 9. The pathways have not been discussed with stakeholders or experts regarding salinization. Therefore, no definitive pathway has been identified.

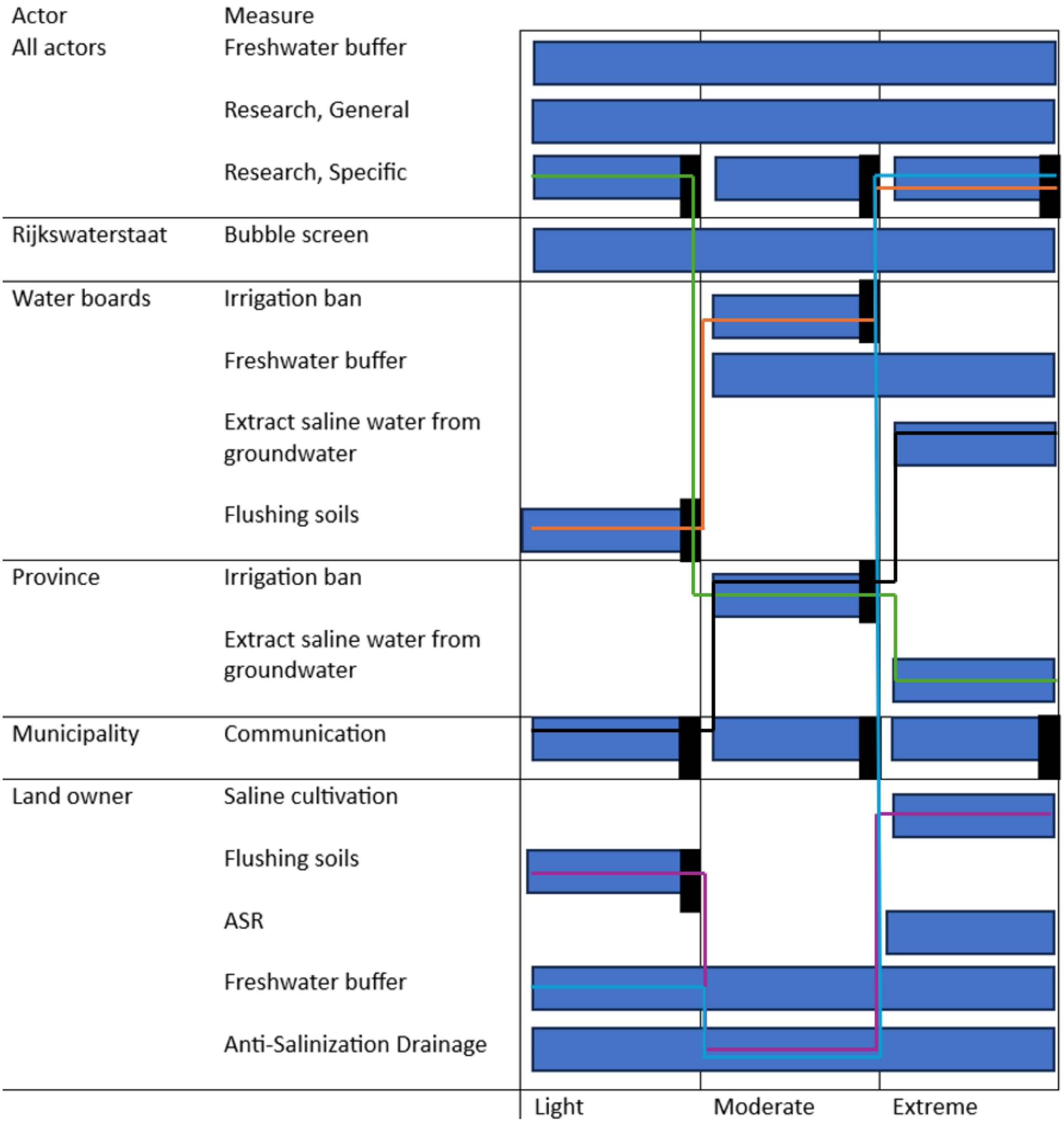

Figure 8 Dynamic Adaptive Policy Pathways Model with example pathways

On the base of Figure 7 a pathway can be chosen. Figure 8 provides example pathways that can be chosen, based on various contextual conditions. The purple pathway (Flushing soils, Anti-salinization drainage, Saline cultivation), might be a pathway chosen by an individual farmer who is not willing to invest in expensive systems. The green pathway (Specific research, Irrigation ban, Saline groundwater extraction) might be chosen by the province, who is willing to invest in measures when the extend of salinization has reached an extreme level. The Orange path (Flushing soils, irrigation ban, specific research) is an example of what a waterboard could do to prevent implementation of expensive measures. The Blue path (Freshwater buffer, Anti-Salinization drainage, specific research) might be a path decided by any actor, if limited funds are available and hopes that in an extreme stage, more information is present. Lastly the black path (Communication, irrigation ban, extract saline water from groundwater) is an example of a path chosen where multiple layers of government work together to try and provide a solution.

6. Conclusion

This study aimed to answer the research question ‘What is the potential of the Dynamic Adaptive Policy Pathways approach aid planners in preventing the negative outcomes of Salinization in the north of the Netherlands?’. With the sub-questions being ‘’what is salinisation & what can planners do to prevent it?”, ‘’What are Dynamic Adaptive Policy Pathways & how does this approach relate to salinisation?’’. In this chapter, first the sub questions will be answered, then the potential and limitations of the DAPP approach will be discussed.

What is salinisation & what can planners do to prevent it? Salinisation is a natural process in delta regions, which is accelerated by factors such as climate change and changes in precipitation. Salinization is a non-linear process. Various prevention measures have been identified. All measures mainly focus on maintaining a freshwater lens to push down saline seepage. The most promising measure to ensure that this freshwater lens is maintained is anti-salinization drainage. However, this measure can only be implemented on the small scale. All interviewees agree that more research is needed to fully understand salinization. Currently, the process of salinization is understood in a general extend, however, specific implications are yet unknown. This has led to a lack of implementable measures in various stages of salinization. The owner of the plot of land has the most responsibility in solving the issue. The landowner also often has the least financial resources. Therefore, information about this issue to make arguments in favour of implementing measures is crucial in preventing further, and possibly irreversible, damage due to salinization in the future.

What are Dynamic Adaptive Policy Pathways & how does this approach relate to salinisation? DAPP is a planning approach that aids planners in decision-making in times of uncertainty. For the DAPP approach stakeholders and experts come together to discuss the issue at hand. Measures and tipping points are identified and based on this information a DAPP model is developed. Providing an overview of what can be done, at what stage of the issue. From this model a pathway can be chosen. After implementation measures are evaluated. If the context changes due to the uncertain factors, the DAPP approach allows for flexibility in the chosen pathway. Through discussion another pathway might be chosen, where other measures can be implemented. This enables planners to take action when faced with uncertainty. For salinization uncertainty has a big impact on decision making. It is currently unknown what the specific impact of salinization will be, therefore, it is hard to quantify the measures required for prevention. As salinization is closely related to drought management, measures against salinization are closely related to measures against drought management. For drought management the responsibilities are divided between various levels of government. A DAPP approach could aid in allocating responsibilities between governments, or private parties. The DAPP model sheds a light on the information available, to reduce uncertainty. In addition to identifying gaps in measures, which could point out vulnerabilities. There is still a lot of planners and experts do not understand about salinization, therefore it might be to early to fully implement the DAPP approach as the only approach to salinization.

In this study pathways were not chosen by planners or salinization experts. To test if the proposed pathways Figure 8 would be desirable, further research is needed. This future research would also provide us with feedback on weather or not the categorisation of the extend of salinization as low, moderate and extreme would be sufficient. Implementing depth of saline seepage or electric current would be a possibility if a specific number is required. However as mentioned in the interviews, the level of which salinization is experienced as a problem is relative. Through a proper participatory process actors could together decide these parameters. It could also be decided that parameters vary from place to place. Salinization has less negative and permanent implications on sandy soils, it could be decided that a specific electric current measured on sandy soil is more acceptable than the same current on clay soils.

The potential of the Dynamic Adaptive Policy Pathways approach mainly lies in providing an overview of the information available and the information that is still unknown. It could aid in communication and discussion between actors. DAPP approaches have been successfully implemented in other aspects of water management, meaning that governmental organizations responsible for salinization prevention would have some experience with this approach. Allowing for faster implementation. On the other hand, it might be to early to implement a DAPP as uncertainties are too big to identify tipping points. That leaves the question what other approach would be more suitable for dealing with salinization. Future research might shed a light on more appropriate approaches, however for now the DAPP approach does show potential. As there is no approach implemented as of yet, implementation of the DAPP approach would be beneficial, based on the findings of this study. When implementing the approach, the limitations need to be taken into account.

7. Reflection and limitations

When starting this thesis, the idea of using the climate scenarios as developed by the KNMI as a base for tipping points in salinization seemed to be the ultimate solution. Mean sea level is seen as the base for tipping points for the climate scenarios. In academic sources salinization was never linked to mean sea level and during the interview stage it came to light that salinisation is a relative problem. The example that was given is that a municipality such as Texel, located in the Wadden sea of the Netherlands, allows for higher salt concentrations in the soil than Oldambt, a municipality located on land within the Province of Groningen. In addition to this, salinization is not static. After multiple dry years, salinization can become a big issue, however, after a wet year, some effects of salinization can be mitigated. Because these boundaries are unclear and are able to fluctuate depending on the context, too little information is left to base scenarios on. Rendering scenario planning useless in this type of issue. If scenarios would be used, sea level rise would not be a good base, as there are many factors that influence the outcome of salinization. Therefore, the depth at which salt or brackish water is found in the soil was used as a base for tipping points in the Dynamic Adaptive Policy Pathways Approach. Due to the differing levels of salinization that are accepted per region, climate scenarios were deemed as an unfit approach to this process.

Dynamic Adaptive Policy Pathways has been developed through academic research and planning practice. Various academic and grey articles have been written about this subject. However, it is important to consider that the same researchers have been involved in the majority of the academic research in addition to the grey literature and evaluations from practical experiences. This does not mean that this body of academic knowledge is insignificant. It does, however, mean that there is little academic critique on Dynamic Adaptive Policy Pathways or the implementation of Dynamic Adaptive Policy Pathways. A broader spectrum of perspectives would strengthen the academic debate surrounding Dynamic Adaptive Policy Pathways

During the interviews it came to light that the interviewees that see salinization as a major problem, worked for organizations benefiting from salinization being a problem. Organizations who are paid by governments to research salinization tend to see salinization as a big issue. Whilst two of the four governmental employees do not see salinization as a big issue. The one farmer, who produces and researches crop growth in saline conditions, does not see salinization as an issue that needs to be solved, but as a phenomenon that requires a mindset shift. The first group of interviewees has a financial incentive to describe salinization as a big issue, just as the last interviewee has an incentive to ignore some negative externalities of salinisation as this could reduce the demand for their products. It is important to consider that the farming takes place on sandy soils, where the effects of salinisation can be mitigated through flushing with fresh water. Whilst the researchers mainly focused on clay soils, where negative effects are not mitigated that easily or cost effectively. In addition to this, it is possible that governmental employees have multiple water and climate related issues that seem to be more pressing, leading to salinization receiving less attention. Whilst understanding salinization and its consequences is the main focus of salinization researchers. To verify if this potential biased perspective stems from a financial incentive or has other origins, a larger sample size is needed.

The development of a DAPP should consist of an communicative approach, where discussion surrounding the subject of the approach, salinization, and its measures is facilitated. It is a non-linear approach that evaluates the effectiveness of the measures over time. Due to time constraints this research did not follow this process. Instead of discussion between the stakeholders, the researcher questioned them one on one and summarized their findings and perspectives. Interviewees in a later stage were able to reflect on perspectives from earlier participants, however, this is not considered a discussion as there is not a mutual exchange of perspectives, as the earlier participant did not receive information or perspectives from later participants. In addition to this, it was not possible to evaluate and reflect on the effectiveness of the implemented measures, as there where no measures implemented.

All interviewees agree that the farmer is responsible for maintaining the freshwater buffer. One farmer was interviewed, but this farmer specialises in saline cultivation. What traditional farmers might think of this responsibility and how they deal with this responsibility, does not fall in the scope of this research. In future research it would be interesting to see if farmers think that they have the resources to ensure that this water buffer is maintained and how maintaining this water buffer might impact them. Would this for example, have an impact on the machinery that is able to cultivate the land, if the land has to remain wet? What would this mean for the crop type that the farmer choses? When developing a DAPP framework through a communicative process, farmers need to be included in the discussion to add their perspective on implementation and evaluation of these measures.

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Appendix A: Thesis interview guide

Problem and problem definition
- Wat is the definition of salinization used by you or your organization?
-To what extent do you see salinization as a problem and to what extent is it a phenomenon that we need to learn to live with?
- Is salinization a problem that requires planning intervention by government?

Measures
- Is it possible to implement measures to prevent salinization, if so which ones?
- Who is responsible for implementing these measures?
- Are these measures being implemented, if so, what are the (preliminary) results, if not, what is hindering implementation?

(Explain tipping points)
- Can you identify the tipping points for these measures

For interviewees not working at government

Do you work together with governments?
Do you feel like governments and planners have enough tools to solve this issue?
If not, what more do they need?

Explain DAPP

Is this a planning tool that would aid planners or would aid you in working with planners?

For interviewees working at government
Do you feel like you have enough tools at your disposal to plan for salinization?
What are common questions governments approach you with?
If not what more do you need?
Do you feel like you know what and when to implement?

Explain DAPP

Do you feel like this planning tool would aid you in your work?

All interviewees

Do you feel like you expressed everything correctly, do you want to come back to previous answers?
Is there anything that you feel that I have to add to my thesis?
Who/what party could I not miss as an interview candidate?