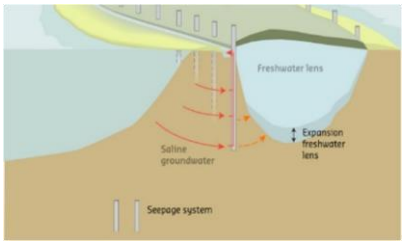
Dealing with salinization in 'Fryslân', an elaboration of costs and benefits of applying 'SeepCat.' technology.



Picture 1. Deltares

Picture 2.: "Digital Etalage", Dutch Library

Picture 3. WUR, vital & sustainable soil

Keywords:
Salinization, 'SeepCat.', Drought, Soil, Groundwater and quality, Sea-level rise, Climate Change, Agricultural sector, Cost-Benefit, Water Management.

M-EEM; Master of Environmental & Energy Management
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List of abbreviations

ASR = water carrying packet storage and win back
KWR = 'Kennis Instituut Water en Research, voorheen KIWA'
KRW = 'Kader Richtlijn Water'
POP = 'Platteland Ontwikkeling Programma EU'
LTO = 'Land en Tuinbouw Organisatie'
UNFCCC = United Nations Framework Convention on Climate Change
CBD = Convention on Biological Diversity
STOWA= 'Stichting Toegepast Onderzoek Watermanagement'
HHNK = 'Hoogheemraadschap Hollands-Noorderkwartier'
HHSK = 'Hoogheemraadschap Krimpenerwaard en Schieland'
AMvB = 'Algemene maatregelen van Bestuur'
NPV = Net Present Value
IRR = Internal Rate of Return
RWS = 'Rijkswaterstaat'
EIA = Environmental Impact Assessment
OESO = 'Organisatie voor Economische Samenwerking en Ontwikkeling'
GIS = 'Geologische Informatie Systeem'
CBA = Costs Benefit Analyses
NAP = 'Normaal Amsterdams Peil'
RD = 'Rijksdriehoekscoördinaten'

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Word of thank

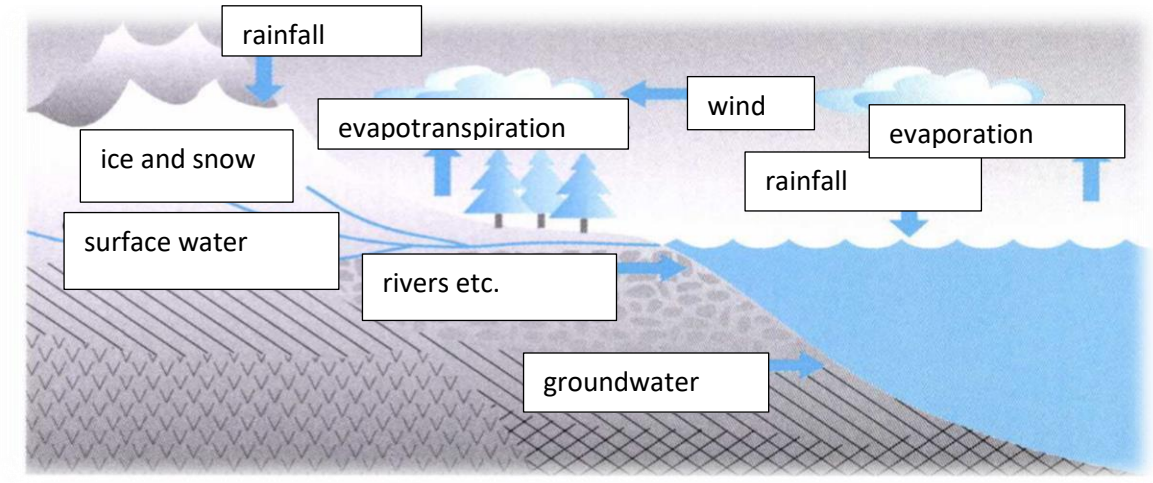
I would like to thank the host organisation the Province of Friesland and especially Mr ir W. Elderhorst for his involvement and guidance during this research. Further, I would like to thank all colleagues and experts at the Province but also outside the organisation in their field for their time, sharing of knowledge and information: 'Wetterskip Fryslân', 'Deltares' Mr dr Perry de Louw, Mrs T. de Vries LTO, 'Potatoe Valley', 'Acacia Water', WUR, RWS, 'Extreme weather insurance companies' and 'HZPC'. The supervisors of UTwente, dr Özerol and dr Lulofs for their guidance and lectures and the other lectures of M-EEM as well, and the staff of M-EEM for their support.
Finally, I would like to thank my daughter who was patient my nephew Sander Hilarides, Richard Bosma and Mayte Leinenga who gave some support on Excel.

Some relevant key concepts

Aquifers
Aquifer= geological formation layer well permeable, like rough sand.
Aquitard = geological formation of low sediment, less permeable for water e.g. clay
*Aquiclud*e = geological formation impermeable aquitard ground layer like clay

Chemical quality of groundwater
The chemical composition of quality of the groundwater is of great importance because only fresh and uncontaminated groundwater is suitable for consumption. Based on the content of Chloride, NaCl (table salt) is divided into three main classes: fresh, brackish and salt. The understanding of the fresh/salt boundary relates in the Netherlands to the fresh/brackish boundary. This is the boundary which is held as the maximum Chloride concentration in water for human consumption. This limit is set on 150 mg Cl-/l.
The chemical composition is determined because of existence of the sediment in which groundwater occurs as by influence through human activity. This can involve contamination (for example increase of the nitrates content), salinization (increase Cl-content) or sweetening (decrease Cl-content) as a result.

The water companies have as measure of quantity mostly the cubic metre (m^3), 1000 litre. In meteorology and agriculture, the measure mm is common. This unit provides for, for example rainfall, how high the water level would rise if the rainfall would be spread gradually on the surface. Instead of '1 mm' can also be read '1 litre per m^2'.



Picture. 3a): The hydrological circle

(After: Davis, S.N. & R.J.M. De Wiest, 1966 and Meinardi, C.R. & G.J. Heij, 1991)

Conduction: transmission characteristics referred to as the unit, EC.

Diffusion: the process of spreading through or into surrounding substance by mixing with it.

Evaporation: the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in the atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration.

Infiltration: is the phenomenon that rainwater on the surface flows into the ground. The water under the ground surface, which is there because of a ditch- or tube system, is also to be considered. Also, the feeding of a saturated (= verzadigde) zone, which can occur because of for example artificial infiltration wells is included.

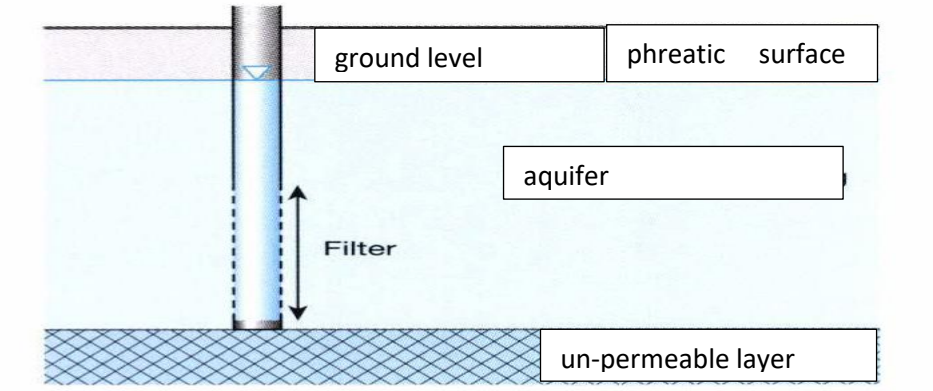
Intrusion: Seawater intrusion is the migration of seawater into freshwater aquifers that are in hydraulic connection with the sea and under the influence of groundwater extraction (Land and Water Hydrology 2003).

'**Maaiveld**' = Dutch term for surface.

Picture 3b).: "Digital Etalage" (Dutch Library)

Permeability: in the Netherlands the permeability of soil is indicated as KD value, the hydrological conductivity.
Like the permeability is a measure for the (horizontal focused) permeability of a certain layer with a certain thickness, there is the resistance against flowing, and against the vertical flooding, allocated. This is the vertical resistance C-value.
As definition of this vertical resistance counts: the resistance which a certain layer (with a certain thickness) offers to a vertical groundwater flowing. This C-value is only allocated to less or nonpermeable layers like clay.

Phreatic aquifer: if the aquifer is not locked on top by a less or nonpermeable layer, the groundwater in this aquifer will be called "phreatic water". In such an aquifer the groundwater is via the permeable unsaturated zone in open contact with the atmosphere. The top restriction of the groundwater in the saturated zone is the phreatic surface. In this situation the level of the groundwater towards the reference surface is the groundwater level.



Picture 3c).: Phreatic aquifer after: Kruseman, G.P., N.A. de Ridder & J.M. Verweij, 1990
(For insight in the yearly supplement of the groundwater the nett rain surplus, the rainfall minus evaporation, is more important than the rainfall alone).

Porosity: although some sediments can have a high porosity, it is not immediately naturally that a huge permeability is going together. Clay is the most famous example which has a high-pores - content but a low permeability. The seeming contradiction is caused because the form, size and interrelation of pores play a decisive role in the permeability of the concerning sediment.
Porosity percentage can differ for young Holocene clay with shale (schalie= sedimentary stones which exist of hard, consolidated clay). During the geological process where clay is converted into shale huge amounts of formation water is driven out.

Rise height: the height according to a reference surface, to which the water rises in a tube which is in open relation with the atmosphere at one side and with the groundwater in an aquifer (=watervoerende laag of pakket genoemd) a bottom layer which transports water and which is restricted at the top and underlayer through an un-permeable layer or free water surface) on the other side.

Saturated– non saturated: holding as much water or moisture as can be absorbed.

Seepage: is the entrance of groundwater to the ground surface in a mostly low laying area. Seepage is considered as well when groundwater under influence of larger level rises which occur outside the certain considered area. This outgoing of groundwater can happen directly at the ground surface, in ditches, drains or via capitular rising.

Sediment: depositing of rocky ground like sand, gravel or clay.
The hydrologic behaviour of the groundwater is also depending about the aquifer.

Unripe clay: clay which is coming from the saturated zone and has no outside characteristics of ripening, thus plastic, without structure and totally unaerated.

Chapter 1. Subject of this research, introduction

1.1. Background

Climate Change is associated with severe problems like, storms, flooding, heavy rainfall, drought, biodiversity loss, evaporation and salinization. We must face and deal with the consequences on our ecosystems and human life. These problems are global in nature and ask for international cooperation and commitment to address them within a reasonable time frame.

During the Rio conference held in 1992 “United Nations Framework Convention Climate Change (UNFCCC) and Convention on Biological Diversity (CBD) were signed to promote global action for Climate Change mitigation and biodiversity conservation (MEEM, 2019). Under the umbrella of UNFCCC, the Paris Agreement was signed by its parties which sets obligation on member countries for reducing GHG emissions with an aim to keep the increase in global average temperature to well below 2 C above pre-industrial levels. In addition, all countries are obliged to contribute towards achieving the United Nations Sustainable Development Goals (MEEM, 2019). Goal nr.: 6, 13,15 are related to water.

The amount of fresh water is estimated on 35 million km^3 this is only 2,5% of the whole water capacity on Earth. The fresh water is divided as following: more than 69% in ice; 30% in the form of groundwater; and less than 1% in the form of surface water (Dufour.F., 1998).

In 1997 Watercourses Convention was agreed that goes beyond the so-called “no harm principle” for international watercourses in general. It also determines that in attaining *equitable* and *reasonable use* all relevant factors shall be considered, including natural, social and economic factors and existing and future uses and their effects.
The convention sets a goal for cooperation towards optimal and sustainable utilisation (Hey, E., 2016).
The European and National Policy and law in the Framework Directive Water established further direction and action as well as the Dutch Delta Program and its subprogram “Fresh Water” did. As a result of both Sea-level rise and more frequent occurring droughts, according to recent forecasts of Dutch KNMI (Climate scenarios, appendix V), salinization has an impact on *water quality.*

Furthermore, the POP3 program to develop sustainable agriculture, the provincial 4th “Waterhuishoudingsplan”, and Frisian Waterboard’s Water Guardiancy Plan are relevant for the context of this research. Salinization is an effect which has among others an impact on *agriculture*.
The Delta Plan Agriculture Water Management gives direction towards cooperation between agriculture and waterboards. The new “Omgevingswet” will give further action to improve sustainable development on a regional level. Participation of citizens, companies and local government will be further established and will area development increase to ensure that Climate Change and its effects will be mitigated, regulated and solved. Because of sea-level rise and forecasted periods of drought (KNMI), salinization has impact on as stated before water quality but also on the soil condition.
Agriculture is one of the most important economic drivers in Friesland and the coastal region is confronted with salinized groundwater. Considering the economic importance of high value crops, the value of fertile agricultural ground and the need for sustainable food production in general, because demand is growing because of world’s population and resources are declining, it is essential that the negative effects of salinization will be mitigated. As well because of drought more fresh water will be needed to restore unfortune damage. Last August, the report of ICCP announced that action is needed to keep food *affordable* and *accessible*. These are UN sustainable goals. Water management is a key factor in this, as well as technological solutions can be, though expensive.

The research objective is therefore to describe and to analyse whether an existing proven solution called 'SeepCat.' developed for a salinization problem in the Dutch Province of Zeeland is suitable for the Frisian northern western coastal area and whether this is the best solution.

1.2. Problem statement

The main goal of this exploring research project is to analyse the economic feasibility of a vertical seepage screen, called 'SeepCat.', along the Frisian coast to mitigate salinization. 'SeepCat.' is a contraction of the English 'seepage catcher'.
The second goal of this project is to design a proposal for a pilot where a vertical seepage screen can be tested and monitored.

1.3. Research design

The main research question and sub-questions will guide this research and the surge for answers. The research main question will be: "*Since the northern western part of the province of Friesland is confronted with negative impact of salinization in two ways, as explained in paragraph 3.3. and the area is sensitive for salinization, how can 'SeepCat.' technology contributes? What are the consequences in the long and short term?* "

The underneath descriptive and analysing sub-questions will support answering the main question and direct the sequence of chapters. In this it becomes clear how complex salinization is, which knowledge is required, how important both water- and soil management are and which technology and (agricultural) practise can contribute and when and which (policy) choices are needed. The formulated sub-questions are:

1.*What is salinization, how does it appear in this region and what are the causes?*
This describing and analysing question will be answered through literature and knowledge of colleagues at the Province during an internship. The results of this will reveal the impact of salinization, the existence history but also the contribution of water management, possible solutions in the short and long term and assessment on continuing steps.

2.*Why is especially the Frisian norther western coast sensitive for salinization?*
This analysing and describing question will clarify the context of salinization. The results will express the importance of measurements in this specific area especially in the long term where intrusion of saline water from sea is moving more land inward but also because of history saline seepage is moving in the underground. Other processes like gas- and salt-mining and soil subsidence have a substantial impact on salinization.

3.Which actors are involved in the matter of salinization?
This describing and analysing question is important to explore where cooperation is needed and can be improved and if there are combinations possible, opportunities, with other matters. As a result, everybody should have advantage of this collaboration and give an impulse towards the sustainable direction of the future where conditions and coordination remain important.

4. *Which law(s) and regulation are relevant, what is the legal framework and policy*?
This describing and analysing question will give insight in how water management is organised. Which institutions and policies have influence on the salinization- and water matter?

5.*Which other measurements are available, and do they work effectively?*
This describing and analysing question will give insight in the current state regarding salinization and possible solutions, effectiveness, negative effects and possibilities for improvement.

6. *What are the characteristics of SeepCat.?*
This describing and analysing question will explain the working and possibilities of SeepCat. and in doing so clarifies the context to assess if SeepCat. is a probable solution in this region, if there are adjustments required and if, are these possible and what will be the costs? Furthermore, which probable options can support?

7. *What is the experience until now regarding Seep Cat.?*
This describing question will be answered by expert interview and literature. The results of SeepCat. will decide if this technology will be a helpful and sustainable investment in the research region and will meet the expectations in solving the problems meant.

8. *How does a proposed pilot look like?*
This describing, partly pre-scribing and designing question will be answered by expert interview, collegial experience and knowledge and pilot design in Province of Zeeland but will require further follow-up after a geohydrological pre-research, and decisions/choices.

9a). *What are the geological characteristics of the research area?*
This describing question is answered by literature, collegial knowledge and the GIS tool. In the subject of hydrology, it is essential to characterise and study and report these characteristics. For a pilot is this as well essential to order and know these characteristics. In this research some first steps have been taken to support this.
b). *How many farmers are active in this region?*
This describing question will be answered by using data and is of importance to have insight in the relation crop damage and investment and advantage of 'SeepCat'.

10*. Which costs and benefits have been defined during this research?*
This analysing but also describing question is partly to be answered by using data, literature and expert consultation. Through colleague know-how financial data has been gathered. This has resulted in three variations. Depending on the goals, the amount of seepage the Province wants to catch there must be first made further choices. This is also needed to have a balanced overview of the benefits. The short and long term needs further consideration and the current transition in agricultural sector as well.

11.*What are the uncertainties?*
For answering this research question literature will be used but also expertise of colleagues and the gaps/boundaries found during this research and current developments.

12.*Which steps will be needed to have the measurement SeepCat. implemented?*
This analysing question will be answered by overviewing all gathered information. The Cost Benefit Analyses is in this research a key factor and has as rule that if the balance gives a negative NPV, a monetary indicator, the project cannot take place. However, an IRR analyses which is a percentage and a sensitivity analyses indicator will be used as well to see if it is justified to start a pilot/project.

Some further steps are given and suggestions which can influence the status in a responsible way. The input of the CBA is in some parts matter of dispute, uncertainty and reason for development and therefore to alter.

13.*Which time scales and scenarios are needed?*
This analysing and pre-scribing question is based on literature, the current KNMI Climate scenarios and forecasts on freshwater shortage, surplus, Sea-level rise, ambitions of the Ministry of Agriculture in 2030, which will need enough fresh and affordable, clean water, Delta plan Freshwater and local development and development of salinization. The impact of Climate Change will increase, but the impact of the scenario “do nothing” also.

In the end of this research will be formulated some conclusions and some recommendations. The references and appendixes can be found as well there.

Chapter 2. Research method

2.1. Practise oriented research

This research can be defined as practise oriented (M-EEM, 2019). This means, the collecting and gathering of information (as well primary as secondary) to asses if salinization in the Frisian northern western coastal area can be solved by implementing of the 'SeepCat.' technology. Furthermore, how costs and benefits are related and how an eventual pilot can be organised. The data and information are connected to research and sub-research questions which are descriptive, pre-scribing, analysing, exploring or designing in nature. The results of these questions are explained in the previous chapter.

The role of the 'SeepCat.' situation in the Province of Zeeland is to research if upscale possibilities are probable for this technology in the northern western part of Friesland and which lessons have been learned so far. Because the research has been done during an internship and cooperation has been arranged with the Frisian waterboard, information from colleagues, congresses, and experts along the network will be obtained and processed. Because of privacy reasons permission will be asked and will be referred to the purpose of the research and the ethical statement where careful and legal use of information has been stated. The information will be obtained by interview (personal, e-mail or telephone) and offered in 'concept' for eventual correction and accordance.

2.2. Research framework

In the underneath schedule the main concepts and theories of this research have been presented.

Most important concepts	Theories
-Salinization	-regarding salinization and the influence on the eco-system and society, agriculture in particular
-'SeepCat.' technology	-Technological qualifications and assessment, effectivity, feasibility, monitoring, EIA and SWOT
-Cost-Benefit Analyses	-Financial and economical analyse and assessment
-Water buffer	-macro-micro economic aspects
-Circular and sustainable use	-sustainable development, lectures 'UTwente' M-EEM

Table1.: overview concepts and theories

The reasons why these theories are used is to obtain more insight and background for assessing the phenome salinization, the relation with water management and the problems which can occur for users and water management but also the societal impact of these. Moreover, the measurements which have been taken so far and which technologies, gaps and knowledge experience have been studied in order to find better and sustainable solutions in the context of Climate Change and the consequences for current and future water use. In this research agriculture has been meant as main user. This is embedded in relevant policy frameworks like: the National Delta Plan, the Delta Plan Freshwater and the Delta plan Agricultural Water Guardiancy and POP3, the Provincial 4th 'Waterhuishoudingsplan' and the regional Waterboard Plan of 'Wetterskip Fryslân'.
Finally, for the analysing of costs and benefits a theoretical background has been used in order to assess but also to provide direction for follow-up research and to take care of an as careful as possible decision frame.

For the first steps in the designing of a pilot area, implementation and monitoring expert's knowledge of 'SeepCat.' has been used and the Zeeland situation. Moreover, geohydrological knowledge and experience of colleagues and employees of the Frisian waterboard, 'Wetterskip Fryslân'.

The answering of the in paragraph 2.1. formulated main- and sub-questions can be found in the following chapters. In the chapters will be referred to the research- and sub-questions.

-The answer to the research question is to be found in Chapter 8

-The answer to sub question one is to be found in Chapter.3

-The answer to sub question two is to be found in Chapter.3

-The answer to sub question three is to be found in Chapter.6

-The answer to sub question four is to be found in Chapter.5

-The answer to sub question five is to be found in Chapter.6

-The answer to sub question six is to be found in Chapter.8

-The answer to sub question seven is to be found in Chapter.7

-The answer to sub question eight is to be found in Chapter.7

-The answer to sub question nine is to be found in Chapter.7 section 7.2.

-The answer to sub question ten is to be found in Chapter.8

-The answer to sub question eleven is to be found in Chapter.8

-The answer to sub question twelve is to be found in Chapter.8

-The answer to sub question thirteen is to be found in Chapter .8

-A SWOT analyses of 'SeepCat.' is to be found in Chapter 8.

-Finally, the recommendations and conclusion are to be found in Chapter 9.

Chapter 3 Literature review

3.1. Introduction

To start it was logical to have insight in geological and water management developing in the Netherlands and afterward in Friesland to have more insight and engagement in the topic. Literature has been studied therefore in the first place. By studying it becomes clear why the Frisian northern western coast is sensitive for salinization and answers sub question 1. and 2. Then will causes of salinization been further deepened, the relation with crop yields and water management and the actors involved but also the developing. The technological and financial aspects of 'SeepCat.' and it's working but also of other measures have been studied by literature review and expert's reporting and interview and colleague consultation. Finally, for the main research goal, literature on NPV criteria which are the most important project criteria and the most important tool which is used in water projects has been reviewed and used as underpin (Aparicio et.al., 2019).

3.2. Developing of salinization in the Netherlands

Salinization has a rather complicated history. Since we live in a Delta Area water from the sea is already infiltrating since the Middle ages. To have a better understanding it is needed to have some basic knowledge of the existence history of the Netherlands. Where salinization occurs has to do with:
- the coastal development since the last Ice Age (Holocene) and;
- the land winning by "polderen", the drying of land and pumping of water also known as land reclamation (WUR, 2011).
We can also say that the country had developed because of the battle against water. In history inhabitants have always defended themselves against water. By building typical hills (Dutch: "terpen"), dikes and windmills they could control the water. In times of War they could use the water as defending line (TU Delft, 2014/2015). The latter situation tackled the existence of salt which was researched then.

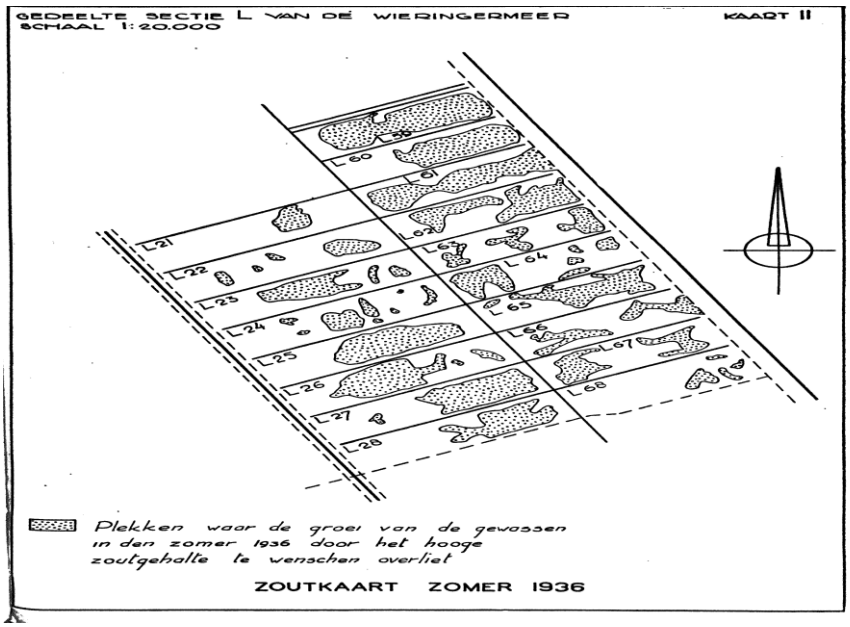
The areas which have the highest Chloride content currently are the areas which were the last ones in the forming of the coastal line in Holocene (8oo after Chr.) and were tidal areas. The Provinces, Zeeland, Groningen, Northern Holland and Friesland are therefore the areas were salt is relatively low under the surface. Other areas are like similar areas where groundwater became saline because of land reclamation since 1300 AD.

The existence of saltwater is mainly because of the heritage of geological Holocene epoque 10.000 years ago after the last Ice Age (WUR, 2011). Global warming in the year 7500 made that the sea level rose and water intruded into the coastal areas. Besides that, there is a movement upward of deep marine salt. Together this forms the salt content in the lower areas in the Netherlands and makes these areas vulnerable for salinization. This is one of the sub questions of the research which will be mentioned in the last paragraph of this Chapter.

More hydrological, it was in the past the common way to equip the water system on economic insight. Overflow of water had to be prevented, drainage was improved, creeks been straightened or made deeper and canals were dug. Rivers were canalized and land was reorganized to improve crop yields. The protection after disasters especially ensured the building of protection measurements which influenced the natural water system, like in Zeeland and the "Afsluitdijk", named together "Zuiderzeewerken". The transportation of waste and other functions will not be dealt with in detail here but had influence on the water quality and Chloride content (TU Delft, 2014/2015).

Because we have fresh water in our lakes and rivers, we can restore the water balance. Depending on the soil and wind, the temperature will rise in some areas of the country and drought periods as a result will increase the damaging effects of salt.
Evaporation therefore has influence on the water system. The year 1976 is indicated during recent conferences "Platform of the "Lake Ijssel', Wageningen and KNMI as a reference year. One of the hottest and driest summers in the previous century. At that time Climate Change was not taken seriously yet and salinization not a treat though some practitioners recognized influence of salt on crops and the subject was already researched.

As stated, before because we have fresh water in our lakes and rivers, we can keep the freshwater balance organised. Depending on the type of soil, height, laying towards coast, evaporation pattern and wind the temperature on land will increase and will because of drought the damaging effects of salt increase. The relation between salt and drought damage quests for more research but is already some knowledge available (WUR, 2018). However, diseases can also play a role. It is in this context worthwhile to name that the chance of infections will increase because of salinization for some crops (Saline Farming Future Congress, Sept. 2019, presentation Maryland, 2019).



Picture 4.: (Thesis, A.J. Zuur, WUR 1938).

In 1970 some researchers were already aware that salinization should become a threat. Degradation of soil, vulnerable crops and problems with water quality would be concerns. Today we must take Climate Change seriously to prevent even worse and we can expect more extreme weather. *Drought* is one of these and *salinization*, although hard to separate in terms of damage costs, interrelated (WUR, 2018) but has thus regional, and broader impact. Both are needed on the agendas of the government and water authorities since Climate Change and its consequences are becoming a severe problem. It is more likely according to recent research of KNMI that droughts in future will occur more often. The drought of 2018 was a wake-up call. Drought has a severe impact on human wellbeing and society but flooding and storms as well. One of the causes of salinization in the Netherlands is the old history of flooding were saltwater intruded and remained (see Ch 1, section 4.).

At the conference in March of the 'Platform Ijsselmeer' on drought last year were together with this more problematic issue tackled. Among others, the subsidence of ground levels, salinization and evaporation.

Newspaper announced that salinization was even a bigger issue than drought, which was extreme that summer (NRC, 2018). The inlet and buffer of fresh water plays a crucial role in this but also other factors like Sea-level rise, and locks.

Because of locks, there is dynamics between the 'Lake Ijssel' and 'Wadden' Sea but protected by sophisticated locks. The damaging salt is caught into basins but because the focus was on keeping the fresh water there was no water used for draining and in this way the salt basins became flooded which caused a Chloride content rising in the 'lake Ijssel' and resulted in salinized water.

Because of Climate Change the sea level will rise and salt is being pushed more land inward as well with consequences for high value agricultural production which is mostly done in coastal areas because of fertile soil. The rural areas need development for now and future generations and having a save food production is essential for societies. Agriculture itself is involved because intensive farming is increasing Climate problems because of emitting GHGs, but also influences water and soil quality. Water management, in each role, is responsible for the water quality and supply, but Climate Change and environmental related problems must be faced together. Cooperation of users is more and more important. For the fresh water supply it will be obvious that the pressure on the 'Ijssel lake' as freshwater buffer for many users and Provinces will increase in times of drought. Moreover, the water quality of this fresh water buffer for among others inlet to agricultural users/areas a concern because salinization of the water in this drought summer made that the Chloride content was above 150 mg/l (see above locks).

Water management and regulation but also operation will remain tremendously important because fresh water needs to be protected and shared but also salinization to be considered ('Rapport eerste beleidstafel Droogte', 2019).

Energy crisis and pressure on still available gas resources but also the salt mining in some areas and projects for creating more nature areas are critical points among others regarding increasing of salinization. The latter is in some way contradictive because when creating saline nature by breaking of dikes, agriculture in these areas will be affected. The Seep Cat. technology can in this situation give some release as compensation in the short term and helps to restore and protect the freshwater balance in the area and can be extended in the long term for a bigger area when increasing of salinization occurs. Moreover, because of 'SeepCat.'the freshwater lens will grow. In Chapter 8 of this report some effects of the Seep Cat. can be found presented in some maps where calculations for the Frisian Groundwater Study have been made which are also related to the long-term Climate scenarios.,2050, 2085. The technological description of the 'SeepCat.' and it's working can be found as well in Ch. 8.

As stated above enough fresh and clean water is essential for economic and social reasons. Also, nature has damage and it takes a long time to recover has been concluded already after the last summer (WUR, study conference on drought, March 2019). Natura2000 areas and drinking water protected areas which are depending on a proper resilient water system, showed difficulties and it was also acknowledged that restoring of the water balance took considerable time in the 'lake Ijssel' after such a drought period. Depending on the soil, first results of research show that before the new dry season started in 2019 the restoring was not enough ('Beleidstafel Droogte', 2019).

The future will ask for structural measurements to keep enough fresh water and of enough quality. Capacity building of fresh water from rainfall in the winter period becomes more urgent.
This research will also cover the ways how salination is treated now, among which principles, what the characteristics of these systems are and what the reasons are why the Netherlands and the research area is vulnerable for salination? Moreover, the research project will focus on the contribution of innovative technology, among which is Seep Cat.

A nice overview of the process of salinization process is to be seen in the underneath picture. It makes also clear what the risks are related to Climate Change.

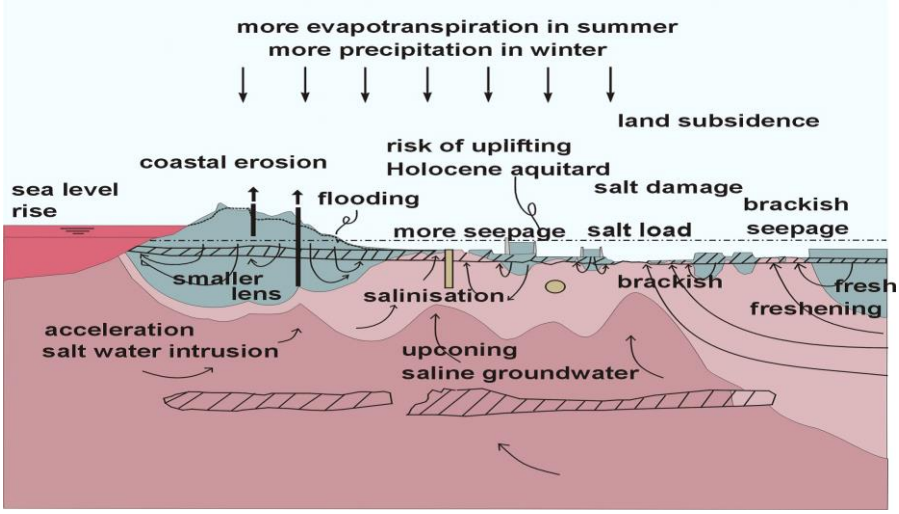


Fig. 1.: Salinization processes at Dutch coastal areas in case of sea-level rise and Climate Change, 'Docplayer'.

3.3. Development of salinization in Friesland

Understanding the vulnerability of the province of Friesland for salinization, the second research objective, starts with its foundation along the coast during Holocene.
As in the previous Chapter has been explained the Province of Friesland is one of the Dutch coastal provinces which arose in Holocene. This implies that the influence of the sea is part of the existence history. Geological processes formed further the land, which is being described in more detail in this section, and finally manmade influences dominated by controlling the sea level rise and land reclamation.

Picture 5.: land reclamation and closing of the Southern Sea in 1914, Geographixs.com

The underground exists of deep layers of clay, sand and peat also called sedimentary deposit.
In the northern western part of the Netherlands are hard rocks deeply situated at more than 1000 metres below ground elevation.
In the underlayer above are hard rocks and large clay layers situated in Friesland were hardly any groundwater movement is or can take place. These layers can be impervious.

That is why the hydrological base, is chosen at the top of these layers. As a hydrological rule, the base is chosen *at the top* of these close to impervious layers. In Friesland this is the Formation of Oosterhout, as indicated in the (hydro)geological profile on p. 28 section 3.5. In the northern western part of Friesland this is under approximately 400 m – NAP (New Amsterdam level) and goes upward to a depth of 200 m in the South eastern part of the Province. The common Dutch names of geological layers are presented in Chapter 7, section 7.2.

At the end of Tertiary Period, (start Quartier Period, early Pleistocene) the sea level decreased, and the Northern Sea basin was filled gradually. The coastal line moved upward. The Netherlands and Friesland became under influence of eastern rivers, the so-called 'Eridanos system'. On top of the "Formation of Maassluis" are found river sediments consisting of rough sand with grind.
The northern western part was part of a tidal area were clay and sand were sedimented. In another part of the Province peat could be formed. A big part of the Province was covered with peat until the sea got more influence again. After 800 after Chr. most peat was flowed away by the sea and some peat lakes were transformed into an inner sea, Southern sea (Zuiderzee) between the Province of northern Holland and Friesland. Afterwards a lot of sediment had been sedimented and formed salt marshes which gave opportunities to settle for inhabitants.
The natural landscape changed to a manmade landscape were dikes and extraction dominated. Geological processes like erosion and sedimentation stopped within the dikes. The geological epoque from the Holocene left clays, sand and peat layers in Friesland. Seen from the Pleistocene sand grounds in the East this forms a layer which gradually develops up to 25 metres to the 'Wadden' Sea coast.
It is needed to explain here that sandy and grind layers are permeable and make groundwater flow possible (aquifer). However, clay and peat layers restrict the flowing of water and are not permeable (impermeable layers). This explains to some extend the water moving in the underground at the coastal zone where clay is the most important soil. In other parts of the Province, peat or sand dominate but for the research the focus will be on the coastal north western part.
Man started to shape the landscape in the early Middle ages. The most important manmade installations were, dikes, peat bog, "polders" (= reclamation) and development of the freshwater bosom (called "Friese Boezem") in 1200-1500 AD.

Picture 6.: Land Geographics.com/het Bildt (Grondwatersysteembeschrijving, 2017).

Until 1300 AD the salt sea arms were protected by dikes at the north western coastal area. However, this did not mean that there was no saltwater intrusion. The priority was to restrict the high sea to flow over the land. Sea level rise and intrusion of saltwater had overruled the natural fresh groundwater for the biggest part according to the study of the Frisian ground water system.

According to this above-mentioned study there are four ways in which the salinization process is manifest:
1. salinization because of aquifer above the hydrological base, with salinization of the Formation of 'Maassluis' and lowest layer packets of the Formation 'Peize-Waalre';
2. intrusion of salinization of salt groundwater over clay layers (Peizer complex: which is "pzc" in current language). The clay layers of the 'Peizer' complex, in the past called "clay layers of 'Tegelen' in the Formation of 'Harderwijk'", are situated in northern Friesland at 150 metres below NAP and move to a depth of 200 m in the southern western part of Friesland;
3. salinization via or of aquifer, over clay layers or not;
4. salinization of the covering Holocene clay layer and local layers under, because of flooding of salt sea water and from creeks and gills which are in open relation with the sea.
The first three processes regard salinization within the groundwater system where so-called *lateral (horizontal) salinization* plays an important role. The fourth process is a more vertical process where salt surface water infiltrates in the soil.

Because of the non-permeable characteristic of clay in the base the process of salinization is probably more a process of *diffusion* than of movement according to ' the ground water system description' of Friesland. It should be considered as well that the Tertiary layers are not everywhere consisting of impermeable clay. There were deep sandy layers occur with salty groundwater can because of vertical movement salinization occur. Because of the variations of underground and therefore differences in permeability the lateral salinization cannot being calculated everywhere as the same in a vertical profile. This can cause that there can be saltwater intrusions under which fresh or brackish water can exists. This is called *inversion*. This is mostly in the zone where salt groundwater flows into fresh groundwater.

At some places in Friesland need to be taken in consideration when analysing salinization that salinization in middle and shallow groundwater can be a heritage of the salinization of the 'Eem' Period (named after the river 'Eem' close to Amersfoort, interglacial period). In this period the sea level rose which resulted in intrusion of saltwater in lower basins. In these areas marine clay had been settled. This is as well in the northern western part as in the southern western part of the Province. This could be the explanation according to the study why salt brackish water exists on top of deeper freshwater lenses, also called inversion. ('Grond watersysteembeschrijving', 2017).
The saltwater intruded far into the country and caused brackish areas, but it cannot be claimed according to this study to what extend the 'Eem' Period is responsible for this. Also, sea level rise and flooding during Holocene can be responsible.

In this Chapter will the ways in which salinization has been threated so far being described and thus manmade actions to control the water system.
Because hydrological development after 1200 AD has worked probably more saline causing than to freshen the groundwater, it was concluded by this study that around the year 1200 the water system in this Province was not in balance. Salinization of the groundwater is so to say, "walking behind the sea level rise" and its connected salinization of the surface- and shallow groundwater.

The picture underneath shows the line towards salinization calculations have been made so far. The profile showed in figure 11 p. 55 represents the same line.

Picture 7.: Orientation salinization calculation Province of Friesland, 2017

Salt mining

Close to the research area in the Province of Friesland is the area characterised because of the low laying towards the sea level of the 'Wadden' Sea. The water system is therefore sensitive, also because the soil composition varies a lot; peat meadow areas with relatively autonomous settlement are interchanged with solid more sandy grounds. Because of this the area is relatively sensitive for negative impacts of soil subsidence. The soil subsidence as a result of salt mining is rather strong and comes relatively fast. The 35 cm soil subsidence will occur over a period of some years ('Rijksoverheid', 2019).

During the mining, the regular soil subsidence will quest for adaptions in infrastructure and because of this some damage will occur. The measurements to decline this risk are restricted to a maximizing of the permitted soil subsidence, and the appointments with the decentral government on the effects of such. Salinization of agricultural ground is a real problem in this area and will increase because of soil subsidence ('Rijksoverheid', 2019).

The interview with the hydrologist of Waterboard Friesland confirmed that they worry on this low laying area.

Gas mining

In 240 locations on land and sea, besides the Province of Groningen, is natural gas being extracted. The Minister of Economic Affairs said that he gradually wants to stop the mining. There will not be given new permissions for gas wining on land (Nu.nl., 2018). In the area above Harlingen the soil subsidence will until 2050 still be there ('Gebiedsontwikkeling Franekeradeel, Harlingen'). The gas company 'Vermillion Oil & Gas Nederland' made together with the local authority a plan to compensate this soil subsidence. This will involve installation of drainage, destination of overflow areas and some groundwater level lowering. In other areas outside Franeker a commission will decide on measurements to be taken to compensate the consequences of soil subsidence.

Soil subsidence as a result of gas- and salt mining is leading in the north western part of Friesland to problems with the water system. Valuable agricultural ground will be offered for extra water capacity is written in the media (Boerderij, 2018). In "Gebiedsontwikkeling" plans (rural development) government is offering in specific area farmers to sell the "valuable" land for water capacity and nature (Boerderij Magazine, 2018). For extensive information on these topics is referred to the 'Wadden' Academy.

3.4. What is salinization?

Introduction

To define what salinization is in this research, a natural science definition has been used in the first place. Secondly, a more general description related to the Dutch historical context and in relation to the user and water management. A picture towards crop and soil level and the cumulative working shows how the process of salinization works.

1.Salinisation is a global environmental phenomenon that affects many different aspects of our life (Williams, 2001a,b); changing the chemical composition of natural water resources (lakes, rivers and groundwater), degrading the quality of water supply to the domestic and agriculture sectors, contribution to loss of biodiversity, taxonomic replacement by halotolerant species (Williams, 2001a,b,) loss of fertile soil, collapse of agricultural and fishery industries, changing of local climate conditions, and creating severe health problems e.g. at the Aral Basin(Treatise on Geochemistry, 2003). The Aral Sea Case is a school example in environmental law nowadays (M-EEM, 2019) and persuaded by the UNESCO as a resource to study and learn from. The tragedy of ones an economic blooming region, where many agricultural ha. were flooded through irrigation is now degraded to unemployment and economic hardship because of wrong water management but also shows that water management, agriculture, ecosystem, economic welfare and health are interrelated. The disaster is one of world's worst environmental tragedies. (Treatise on Geochemistry, 2003)

2.Saltwater is the primal substance of water on Earth. Fresh water is composed from it because of precipitation of evaporated saltwater. In this way fresh water is in fact a sediment of saltwater. The Dutch subsoil exists from a lot of salt and brackish water. This is remaining seawater because of flooding in the last 10.000 years. On top of this salt/brackish water, is a layer fresh water which is adduced by rainfall, snow, hail and rivers like Rhine, 'Maas' and 'Schelde'. Since a long time, the Netherlands must face an increasing shortage of fresh water, while saltwater causes more and more problems (Dutch Library, program text Water party, "Water Natuurlijk", Election text 2019).

3.Salinisation is the state when water is too salt/Chloride for optimal use (translation from Acacia Water, report Brackish perspectives). This definition is based on three elements which clarify when salinization is a fact:

- An increase of salt/Chloride in the water is occurring
- The user finds that the water is too salt/Chloride for its purposed goal
- The water guardiancy finds the water too salt/Chloride to achieve her goals.

These three elements reflect the problem of salinization within the field of water system, user and water guardiancy ('Stowa', 2009).

The classification of the several water stages, fresh, brackish and salt, and the dynamics in the underground can be seen in underneath figure 2. There has made a distinguish between groundwater and surface water: the softer colours represent groundwater; the brighter colours represent surface water.

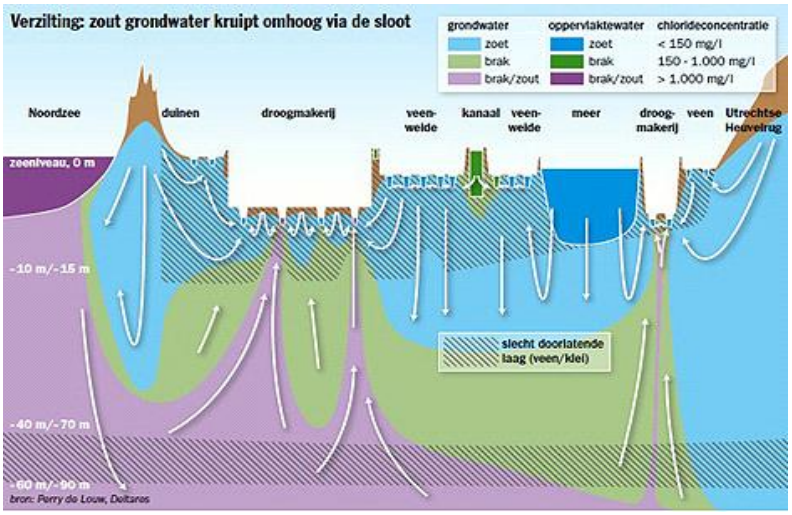


Fig.2.: Fresh-Brackish -Salt, 'Deltares'

To understand how salt can infiltrate some hydrologic explanation will suffice because water is among others the carrier of salt. The Dutch Dr P. Harting (1812-1885), who studied the movement of the underground water in a systematic way in the late 18th century, noticed the behaviour of the water column which was later formulated in a scientific law named after the Frenchman Darcy.

Because epidemic diseases like Cholera were related to drinking of water, the need for drinking water institutions and drinking water governance developed. The knowledge originated from the drinking water matter gave finally proper insight in the moving of groundwater and the relation to the geological context. The existence and role of fresh water from dunes became as well important for cities like Amsterdam and as situated in lower and a mostly brackish water area the development of research boosted which gave more hydrologic knowledge. *The principle of Badon-Ghyben* had been discovered which declared the existence of freshwater bodies under dunes and its floating on salt surrounding groundwater. This principle and insight are nowadays still of great importance for the existence and protecting of fresh water needed for among others food production and drinking water but also useful for the developing of technical solutions like for example 'SeepCat.' to combat negative effects of Climate Change.

<u>Ground water (geo)hydrology essentials in a nutshell</u>.
Water moves in the underground via pores, joints, fractions and other spaces. The permeability of a layer is mainly determined by the space capacity and not by the total porosity. In general, it can be said for un- consoled (= sediments that the permeability increases with the size of the grain). In consolidated sediments and crystalline rock is the permeability also determined by the existing crack system (De Vries, 1980). The science which studies the flowing of groundwater is called geo-hydrology. In this sub-science of hydrology, the mathematic equations which describes the flow of groundwater in the underground are well-known, but it remains hard to make forecasts, because as well the profile of the underground as the disposal of groundwater to the surface are rather unknown according to Dutch Delft University involved in hydrology (ocw.tudellft.nl).
The research of the Frenchman Darcy is of importance here. He discovered that there is a linear relation between the specific pressure of groundwater and the rise height. The proportionality constant between these units is called the permeability of the underground.

This discovery has resulted in the law of Darcy, which forms nowadays still the base of all geohydrological calculations of groundwater moving in porous media. (personal announcement W. Elderhorst, 2019).
A database with available knowledge of the underground and its profiles to certain depths is nowadays available at the Dino-desk. GIS as a comprehensive computer program with many functions for modelling, calculating and visualising of current and future scenarios an indispensable tool for professional research and employees in the water sector and supports the making of hydrological maps (Personal announcement W. Elderhorst, 2019).

When an aquifer (=wvp) is covered on top layer by a separating layer then this is called a closed aquifer. The water in such a packet is called 'pressure water'. If the separating layer or cover layer omits on the upper side of the aquifer it is called 'phreatic water'.

An important unit in geohydrology is the rise height (= stijghoogte). This is the height in a water column in a perforated rise pillar. When the rise height of an aquifer is measured on a map, and lines of similar rise height have been drawn, then a so-called 'isohypsen' map is developed. The groundwater level is perpendicular on the 'isohypsen'. The moving pace is according to the law of Darcy proportionate with the piezometric level of the 'isohypsen'. Commonly, the moving pace of groundwater in an aquifer is in Dutch circumstances ca. 10-150 meter a year. The piezometric level is under natural conditions mostly 1/400 to 1/3000. However, many differentiations occur (personal announcement W. Elderhorst, 2019).

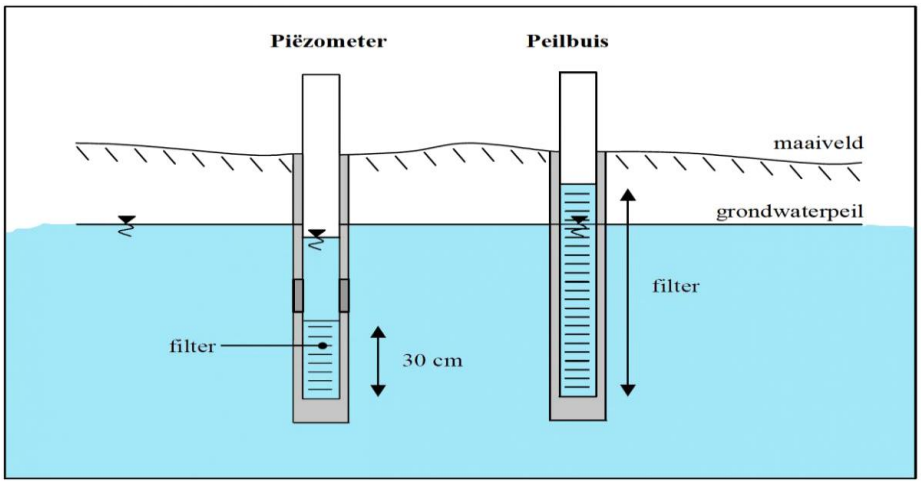


Fig.4: the measured rise height of water in a piezo metre, Ecopedia

For the functioning of the quality of groundwater for agricultural use, the main problem in this research, it is relevant to know more on soil and salt tolerance of crops. These aspects will be dealt with in the next paragraph. What salinization is and the causes, the answer on sub-question 1, is summarised as follows:

a) internal salinization:
- the amount of salt in the Pleistocene under layer.
- the pace in which the salt is transported to the rootzone of crops (Alterra,2011).
b) external salinization: Chloride which is transported via the surface water (Ter Voorde and Velstra, 2009). This salt is coming periodically into the Frisian Bosom and "polders" because of water inlet.
c) passive external salinization: when brackish or salt surface water is becoming more saline by influence of severe salinization problems elsewhere.
d) after drying of seawater salt can be spread. Salt spreading after drying and wind and afterwards is coming into vegetation and then in groundwater under this vegetation.

This cause is only for a small strip along the coast relevant. The Chloride content varies locally from 30 to 600 mg/l (Stuyfzand, 2007).
e) agricultural activity because of increasing evaporation and use of certain fertilizers (Stuurman et al. 2006). More evaporation is caused by irrigation and rise of level of groundwater because of capillary water inlet.
f) sea-level rise pushes salt land inward.
g) historical marine sediment in shallow clay layers (typical for the Netherlands) but locally differentiations in accumulation. The Chloride content can vary because of this locally from 2.000-15.000 mg/l (Stuyfand, 2007).
h) flooding of North Sea and storage of this sea water in marine sediment has probably caused for the biggest part the availability of salt and brackish water in northern and western area of the Netherlands. This is part of the answer on sub-question 2. In the upper kilometre of the active circulating groundwater in this area the Chloride content in the groundwater therefore varies between 2.000-15.000 mg/l (Stuyfzand, 2007).
i) intrusion of seawater is a result of land reclamation, improved water disposal, groundwater extraction, density differences between salt and fresh water, low laying of these areas. The current position of the salt intrusion frontier is 1,5 to 6 km land inward (Stuyfzand, 2007). This frontier represents ca. 1000-year-old Northern sea saltwater and is spread in a pace of 5 to 30 m a year depending on certain factors (Oude Essink, 2007). The potential intrusion will be up to a maximum of 30 km land inward. This means that for the coming 800 to 5700-year salinization because of intrusion of seawater forms for a bigger area a treat, next to soil subsidence, the depth of the groundwater surface, the hydraulic resistance of the cover layer and the permeability of aquifers. (Oude Essink, 2007). The Chloride content in groundwater as a result of intrusion of seawater varies locally from 14.000 to 18.000 mg/l. This answers for another part sub-question 2.
j) because of blending saline water can change fresh water into brackish water. This happens because of *diffusion* or *dispersion*. Blending by dispersion is going faster than diffusion. It happens at large depths but can also occur near shallow clay layers such as in the ‘lake Ijssel’ area. Locally, the Chloride content in groundwater varies because of blending from 100 – 100.000 mg/l (Stuyfzand, 2007).

3.5. Soil

Introduction

To describe and analyse the influence of salt on the soil and to know more about the soil existence in the area of the pilot, this has been researched and is the pilot area the boundary in this research regarding this. Soil is a crucial factor in the process of salinization.

As the underneath profile shows and which has previously been described (par. 3.3.) the geological coastal area consists of several different layers. In the northern part of Friesland, it exists mostly out of clay. (personal announcement, W. Elderhorst, 2019). See also underneath picture.

The top layer (green close to Harlingen in picture) is the fertile soil where agriculture as activity can be done.

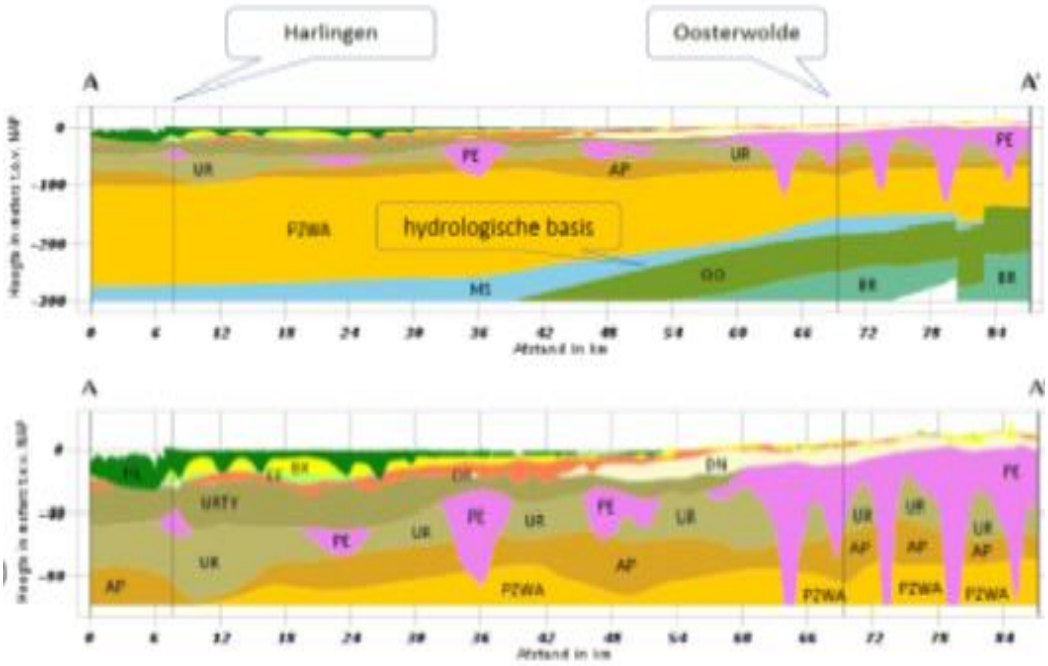


Figure: 5: Profile hydrological base Province of Friesland, J. Rus, from: 'De Friese grondwatersysteembeschrijving'.

A more detailed example of the geological profile of the coastal area is showed here:

✖

Identification:	B05E0011
Coordinates:	169873, 591228 (RD)
'Maaiveld'= surface	2.50 m according to NAP
Depth towards surface	0.00 m - 17.90 m

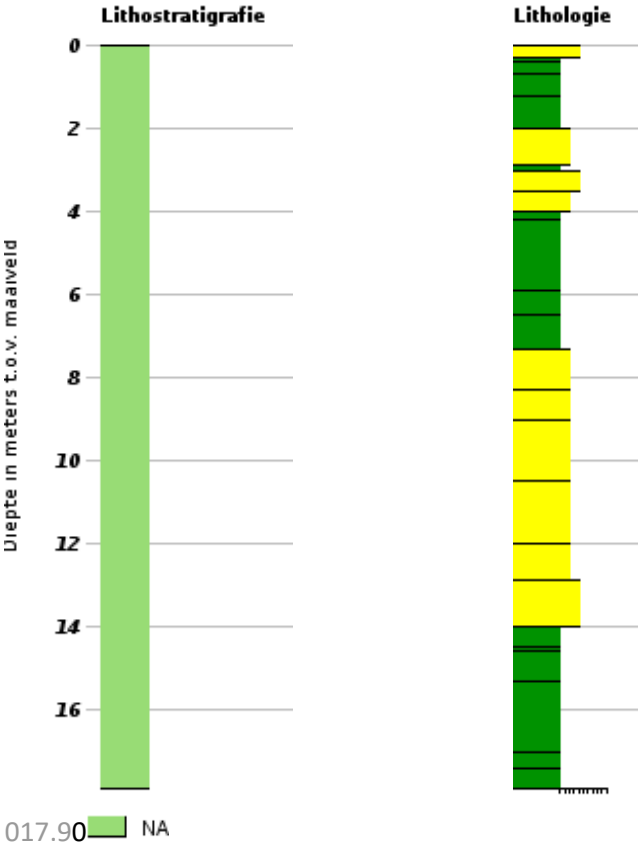


Fig.3: Profile from part pilot area, 'Dinoloket' (2019)

*) The exact profiles and information can be found in 'Dino-loket '.

The profile makes clear that these typical green clay layers in this coastal area can vary with also sand layers in between which is shown in the above drilling profile description.

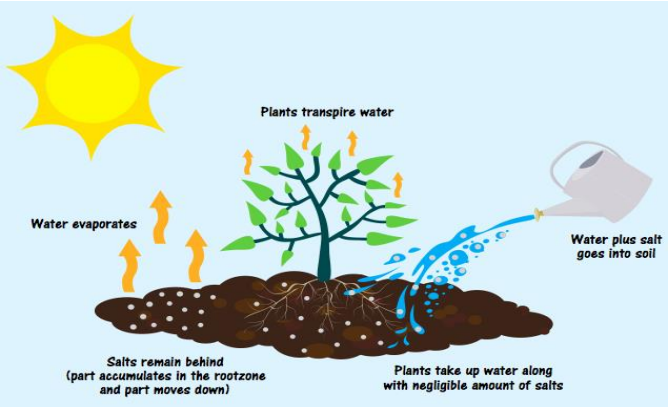
For the pilot in this research the coordinates in this research are described in App. III.
In chapter 7., where the pilot and some needed steps are described, more details are given but this is part of the pilot design and needed for further development of the pilot.

The soil characteristics in the area clarify why this area is sensitive for salinization and to what extent. Which lessons must be learnt from this and how and what adequate solutions can be developed? A geohydrological follow-up research will be needed first to give more direction to a definitive design of an eventual pilot. Salt intrusion like illustrated in fig. 1, p. 18 out of sea and increasing because of Sea-level rise is understood because of coastal laying. This has an impact on the soil as salt is being transported by water and explained in par. 3.4. Other factors for intrusion have been mentioned there as well. The quality and composition of soil decides which crops can grow. The area has a fresh-water cultivation. This means that the availability of freshwater results in the growing of certain crops like high value (seed-)potatoes.

Furthermore, this research learned that there is in the ground the probable existence of so-called unripe clay which has an impact on the dividing in the soil (Acacia, 2019., A. van der Heijden, hydrologist) and the transport of water. This has been associated with physical ripening and determines the firmness but also ability of rooting for soil which develops as a result of ripening process. Unripe sediment cannot be taken into cultivation. ('Ned. Bodemkundige Vereniging').

Soil processes can be damaged and because of this diseases and another damaging impact, salinization, can increase. Sustainable ongoing soil management is therefore crucial and important and especially in coastal areas. The risk maps of the 'Spaarwater project' show where the existence of this unripe clay is and where this should be considered (App. II).

Because of the, fortunately meanwhile decreased, contaminated river's water of Rhine and Maas from the South from potash Alsace industrial disposal, there had been salt influence via the water system in the soil as well for example using flushing water from the 'Lake Ijssel'. In the soil the salt is accumulating because of evaporation in summer. Drier periods which will happen more often because of Climate Change and will affect the structure of the soil in general but with a salt content in the underground it will damage this, and it will slump. The top layer can become extreme salt until more than 110.000 mg Cl./l. (personal announcement W. Elderhorst). Because of rainfall the salt can be disposed out of the top layer. If not, accumulation will happen.



Picture 24.: Salt accumulation mechanism in the root zone of irrigated land, CGIAR, "Making the case of reusing saline water and restoring salt affected agricultural lands"

Deeper sediment layers have a more stable salt content. At higher laying areas and sandy bottoms dis-salinization will go faster. In ditches, lakes and canals with water bottom dis-salinization will go slower. Deep in these bottom salts can remain long (Rijkswaterstaat, literature study 1995).
Because of irrigation of water with high Chloride content, salinization will increase and at the same time degrade the soil. Though salt can be flushed within 1 to 4 years, but it takes 8 years to recover old clay layers with a low Calcium content (Nieuwenhuizen et. al, 2003).
So, the way in which irrigation has been done has an impact (Hillen, 2000). Conscious agricultural practise is therefore needed to prevent and to solve salinization. Next to this the general global warming (surface heath) has influence on processes in the soil (ScienceDirect, 2019).

The process of degradation of structure of clay grounds is happening due to salt existence because adsorption between Calcium and Magnesium ions is exchanging towards Natrium which causes the soil becomes sensitive for constriction. This means as well *swelling* as *shrinking* effects, with among others Oxygen shortage as a result. With proper actions like flushing by drainage and expel of Natrium by adding Calcium through cast (=gips) this process of contraction and degradation of sediment can be influenced but needs fresh and qualitative water. Next to the fertilising of soil the use of salt tolerant pioneer crops could in general make the soil fertile again.
But again, moistening the land with salinized water is not solving anything and will not improve the soil structure and its capacity of keeping the fresh water, which is extremely needed in the future and to prevent worse developments now (Zeeland farmers insight, WUR edupot). The use in Western European countries of large machines, tractors, will degrade the soil structure as well is the opinion of the hydrologist of the Frisian waterboard ('Wetterskip Fryslân', 2019).

Moreover, the *purifying quality* of soil of water and the storage of Carbon needs to be re-valued especially in the age of Climate Change which is not a reason to ensure that water coming from above or sideways because of human activities should not be clean and safe.

Biodiversity can help to restore space and drainage capacity of the soil. Small animals like worms create space and air in the underground, eat at the same time old plant rests and produce organic material which is a natural fertilizer. Biodiversity is also important for the soil and water drainage (Bottom ecology, edepot.wur.nl).

It is relevant in the global picture and UN sustainable goals to name the fact that 60% of the world's agricultural food production ground/soil is degraded because of salt (Prof. P. Vellinga VU, in 'Wadden' Academy announcement 'Saline Future Congress 2019'). To stop salinization will contribute towards the sustainable goals and recovery of Earth's resources. The attention is now on the surface and groundwater but should also be put on the soil(structure) itself. Soil plays a key role in the capturing of freshwater, but freshwater is needed as well to stop salinization as for certain food production. The crops in the northern western part of the research area are to a certain extent vulnerable. There is still enough flushing water but as last year showed there can be a ban because of prioritising and damage will be the irreversible result. It is obvious that farmers here depend on fresh-water management for the production. Effects of Climate Change need to be solved together (Schrijer, 2012) on soil-,ground-,surface water level, an ecosystem approach needed, practised by farmers as well.

New technology can contribute like infra-red (presentation Province colleague, April 2019). At first sight surface can look vital (green) from the air, but deeper in the soil a white gloss can appear and indicates there is salt in a ground layer which means the soil is not vital. The so-called 'Freshem technique' makes use of Airborne electro-magnetic research which is rather expensive but can detect hidden processes in the ground. It is not a measure but an instrument to have more control.

To summarise and answer part of sub question 4.: the salt concentration in the soil is mainly determined by: evaporation, rain, flooding, ripening of layers, and seepage. The last one can also mean fresh water but in the case of damage of salinization the saline seepage is meant. The eco-system circle in agricultural sector and water management is needed for now and future water management and contributes towards mitigation of salinization. A vital soil generates higher yields and will store fresh water. This is needed to keep the salt deep enough and store carbon. The latter to reduce Climate Change impact. Measurement where fresh water is protected will contribute towards a vital soil. In Chapter 6 some have been listed.

3.6. Crops

Introduction

Some agricultural/plant physical knowledge is needed to obtain understanding of the salt effects. These are also specialised fields and ongoing research in order to understand more about the reaction of plants towards salt has been initiated in the northern Provinces.

There are considerable differences determined regarding crops tolerances, among as well agricultural as natural crops (Paulisson et.al 2007; Van Dam et al. 2017). One common feature is that salt causes damage on the rootzone and probably on the leave zone (UvA, 2015). Furthermore, for a plant essential water transport problem (osmotic pressure in soil moisture causes a kind of sucking drought effect in the plant root and because of chemical processes toxicities (ions) happen (Acacia, 2012).

Some plants can resist salt others are much more sensitive. Most plants survive a temporary salt influence (Rijkswaterstaat, literature study 1995). Plants will protect themselves by changing the way of their roots e.g. instead of deep rooting more spread and broader (UvA, 2015).
Additionally, salt has a negative impact on the working of pesticides, which preferably should not to be used, but in the nowadays market regime not yet able to ban out according to a young farmer practitioner and needed to protect crops from diseases (Meeting Salinization , July 2019 'Holwerd'). Salt will therefore damage the farmers income in more ways because the pesticides will not work accurately and the danger to use more which causes an undesirable and unsustainable vicious circle and touches again upon the total condition of the soil and water quality. This concern was also mentioned by a bulb flower farmer during the conference on drought in March 2019 of the 'Platform Ijsselmeer'. More about this will be found in Ch. 8, Cost and Benefits.

Some initiatives like "Fjild lab" ('fjild' = Frisian for field) contribute towards knowledge and collaboration (Meeting on salinization, July 2019 'Holwerd'). The saving of freshwater needed for flushing to ban the salt and keep crops vital will become a growing priority in times when droughts will occur more often.

Stuyt et al. (2016) assessed and analysed the information about salt tolerance of crops in the Netherlands from the period 1950-2015. The result of this desk research is a specification of salt tolerant threshold (also called "salt damage threshold") for 35 crops and crop groups, connected to the salt content of irrigation water.
However, the scattering in measured salt tolerance thresholds must being attributed to variable factors like:

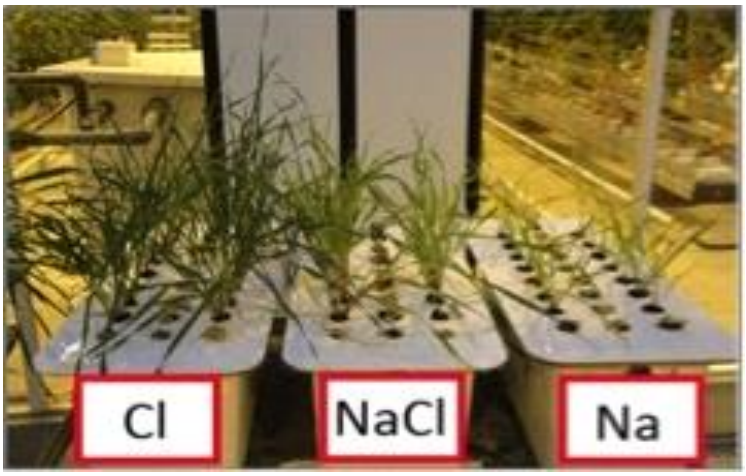
- the salt concentration in the rootzone;
- the soil characteristics;
- the disposal of water situation;
- the climate situation;
- the duration of the exposure of salt;
- the adaptation of plants towards salt stress;
- the adaptation of plants to changing circumstances.

(Stuyt et al., 2016).

Additionally, in the report of STOWA "leven met zout water", the importance of the period *when* crops have been influenced with salt should be considered. For example, during germination or after flowering of the plant makes a difference.

Moreover, further research on the *grow stages* of plants which effects the salt tolerance will be needed according to recent research ('Stowa', 2018). In literature from abroad this fact in arid areas has been acknowledged but these tests cannot simply be used in Dutch and another climate situation. Knowledge from farmers/growers combined with knowledge on plant physiology and tests will be needed to have more valid salt tolerance information. The several grow stages of a plant are an important and relevant aspect regarding salinization, though expected but not tested and valid enough. Tests done with crops (Texel) show already another picture and have a test underpin. A model like SWAP-FROST should also be completed with knowledge on the variable of salt tolerance during plant stages is made clear in report, '*Relation between salt tolerance and grow stages*' ('Stowa', 2018). For as well agriculture as water management this knowledge is needed to have acceptable and valid information and to make progress regarding salinization. When to manage certain water, levels is related to the growing period and essential for agriculture.

The relation between salinization and drought is acknowledged though to separate damage costs caused by salinization or the lack of fresh water difficult to measure. Research says that the tolerance of crops for drought is less variable than for salinization. Probable cause could be that on drought the *osmotic effects* dominate while on salinization as well the *toxic* as *osmatic effect* play a role (Stowa 2018). Though more research on drought effects in the Dutch non-arid Climate will be needed. In "Analyses of salt tolerance", Stuyt (2016) are knowledge gaps on this matter mentioned. A dynamic risk map which varies from 1st of April to 1st of October based on crop plan, structural salt exposure of rootzone etc., thus dynamic parameters which influence the salt content, recommended. Knowledge on the black box of the plant to obtain insight in the critical periods for the plant, specification of signals of time.



Picture 9: Van der Zee, (2013)
Snapshot of crop development after three treatments with the same salt level but absence of possible toxically Natrium (treatment CL) or Chloride (treatment Na), or as the salt is almost totally determined by kitchen salt (NaCl).
(more information about this research can be found at: (Katerji, et al., 2006). From: Delta proof, 2018.

3.7. Salt tolerance and measuring

Introduction
Related to the main subject of this research salinization and to deal with damage calculation in order to balance if and which measurements are justified to solve salinization, the salt tolerance of crops is an important and needed indicator. Measuring is an important instrument and gives certain control about the salt levels and state of the water quality. This is directed in KRW ('Kader Richtlijn Water').

The salt damage which the crop (group) can experience is not only being characterised by the salt tolerance threshold. Also, the salt sensitivity, to know the percentual yield revenue which causes salt damage as a result of salt concentrations above the salt tolerance threshold, is of importance. The sensitivity is commonly visualised as a slope marked as a
"ECslope" in the underneath figure. The damage function is shown in weight percentages of the yield per unit increase of EC (in dS per m) or per 100 mg per l. increase of Chloride concentration. The damage threshold and damage functions have been stated in tests in relation to EC or Chloride concentration in soil moisture, rainwater and for water saturation of the soil in a so-called 'saturated paste' (United States Salinity Laboratory Staff, 1954; J.D. Rhoades, 1982.
The information above is related to growing of crops. However, outside the growing season can salt being flushed out of the soil as mentioned before.

How much water will be needed can be estimated as a function of EC of rainwater, the EC of drain water, which is acceptable, the moisture content of the soil when water saturation occurs (Brady & Weil, 1996).

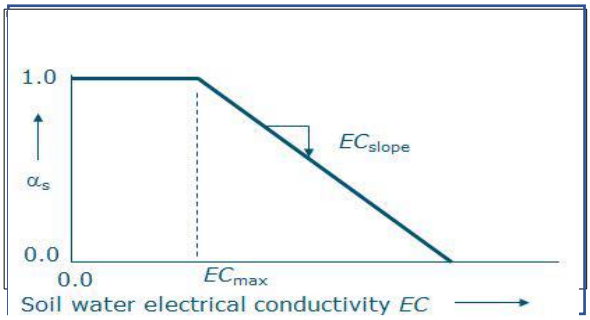


Fig. 7.: WUR, “deelrapport leven met zout” (2007)

EC slope = damage function, point where damage will occur.
a_s = crop yield

*) the EC is not only formed because of Chloride content but has determined by all dissolved ions

Clevering et.al (2006) researched by model simulation how salt drainage water influences in the sediment moisture with regard of the production of potatoes. It was found that the Chloride content was not that much higher than in regular drainage water with the “rule of thumb” can be measured. Based on this the norms for the surface water quality for regular drainage should be kept probably equal as the damage thresholds for sediment moisture. After infiltrations via drains, instead of regular drainage, the ratio of concentrations in the infiltrated ditch water and sediment moisture can vary in the rootzone.

In the “deelrapport; zouttolerance of agricultural crops” (WUR, 2007) detailed information on the influence of salinization on crops has been given.

However, the assumptions which are made to calculate the damage thresholds regarding sediment moisture to damage thresholds regarding rainwater in open ground are very rigid. Therefore, the damage threshold is estimated (’Leven met zout water’, 2007).
Ploegman (1975) stated these for tulips for example at 130 mg Cl. per litre soil moisture, but on the base of the same data also 600 mg per l. could be used. The research on the saline farm shows similar results (table 2 page. 37). For a first exploration of effects of saline water on agricultural production can be used according to the “sub-report salt tolerance of agricultural crops” the ordering in salt tolerance classes. This will be the best despite the unreliable database (WUR, 2007). Moreover, WUR report says; “yield does not say all”. For some crops the quality damage because of salinization is bigger than the loss of weight of the yield (WUR, 2007).

<u>Measuring of EC</u>

Electric conductivity of water arises if there are enough electrodes in the water available to have an electric stream running. In pure distillate water are less free electrodes available. Pure water has therefore a low conductivity and a high electronic resistance. If substances will be resolved in water, then there will be a separation between positive and negative charged particles. Then there will be running of electrodes in water. The more charged parts in water, the higher the conductivity.

Conductivity before 25 °C is measured in the unit: *Siemens.*
Conductivity is for a part determined by the temperature of the water. Measuring values, obtained at the same temperature can be compared. Values obtained at a different temperature need to be corrected to a temperature of 25 °C.
In freshwater the conductivity is low in relation to and is measured in the unit *micro Siemens* (µS). In Seawater the conductivity is much higher, and the value measured in unit *milli Siemens (mS) (Metreseys).*

Although measuring equipment like an EC meter is expensive it is useful to have more control on salinization development. As the table shows (see App. I) the values can differ very much although taken in the same area. In Ch. 6 the project "Boeren meten water" is working with these meters. The farmers have equipment to measure the EC content in their parcels. This data will give needed information and regional data and therefore an instrument to calculate damage. It is also advised in "precision agriculture" (Gent University 2015). This is practised to use water and resources efficient and avoid evaporation.

Then to summarize: the damage threshold is the Chloride content or the EC under which no damage on crops occurs (Fig. 7). The damage function indicates whether the crop yield or quality reduces when the Chloride content is increasing. There is a linear relation assumed. In this research for some most important crops in the pilot area this has been calculated and related to the distance of the sea. The results show that there is a linear relation. One result of potatoes is shown underneath. The others can be found in App. VVI.

z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
z (potatoes)	0	1,75125	3,5025	5,25375	7,005	8,75625	12,25875	14,01	0
	14,01								

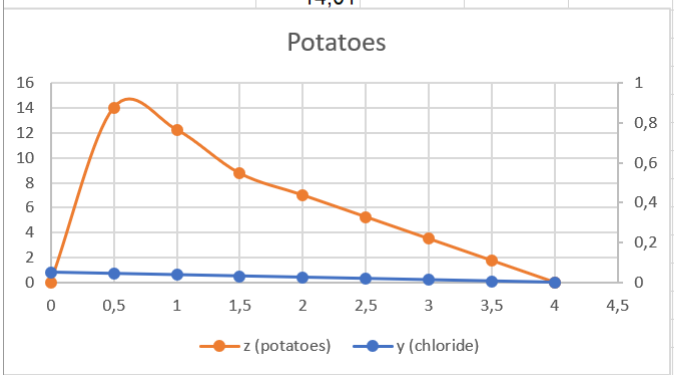


Table 5: potatoes and damage because of Chloride content water and distance to the 'Wadden' sea

Own measuring of Chloride contents in ditches in the pilot area gave some direction in the situation of salinization in the area. There are no regional data at CBS on yields. For results of the measuring App. I is referred to here. The measuring shows that there are large differences although measuring was in the same area. There can be more explanations for this which will be described underneath.

The reasons of influence in this (pilot)area can be:
- less wind because of dikes which influences the temperature;
- the flushing of water by waterboard which influences the Chloride content of the water;
- influence of so-called artworks (= civil engineering) like "vishevel".
- the influence of the 'Wadden' sea.

3.8. Crop management, adaptation strategy

Introduction

Although some practises have already been mentioned it is in order to be more complete that some practises which are part of the solvation of salinization or can be are stated below in short. They form a part of the measurements to be taken and belong to the *adaptation strategy* on farming level. This is part of the answer on sub-question 5.

1. Decreasing of organic substance of the soil

-To decrease the organic substance of the soil is mentioned as an action in the agricultural magazine ('Nieuwe Oogst', 2019). It might can play a role, but sceptics has at the SPNA (a northern test farm) been expressed because the numbers need to be re-validated. This quests for more research.

2.Mulching

Application of soil coverage or mulching treatments may also improve crop performance under saline conditions (WUR, report 614, 2016).

3. Intercropping

For example, growing of two or more crops at the same time on a single field, is an ancient practise, still used in much of the developing world. This type of farming with a combination of moderately salt tolerant, like Broccoli and salt tolerant crops, like Barley can especially be practised on slopes to reuse drain water. This is able when the growing calendars are in one line.

4. Salt tolerant crops

Since knowledge on Climate Change was initiated the call for research on saline farming had among others in "Kennis over Klimaat" consortium been executed. Underneath an overview of salt tolerance of crops which had been researched during the project Saline Perspective under saline circumstances. On the isle of Texel in cooperation with University of Amsterdam and Wageningen tests and experiments were initiated. Unfortunately, last week the farm went bankrupt. They suffered from solvability problems. The market is not ready yet and probably the production too costly because of labour. The production of one ha. Samphire ('Zeekraal') will cost 40.000-euro labour costs. Including other costs as the expensive seed, the total costs will be 89.000 euros per ha. ('Teelt' & 'Klimaat', Wageningen World).

Other new crops for the Netherlands like Quinoa and Spelt have a high salt tolerance and can be an alternative.

Saline farming is as mentioned before an adaption strategy. It is still under developing. On Texel is still research been done.

According to the report of Test Saline Farm Texel (2015) the existing salt tolerance tables are not a good base to make policy with and remarked. The underneath table in which, based on tests in report 'Zilt Perspective' and some other projects on Texel, the changes are made visible in colour. For carrot, onion, cabbage and potato had per crop large differences per variety been observed. This is valid for probably each crop is the statement of Test Saline Farm Texel. A definite determination of the salt tolerance in the Dutch Climate zone askes for more years of research and a field research location like Texel. Unfortunately, the test farm went bankrupt last August. However, the research part will be continued.

The underneath table shows the most import crops and their tolerance level researched at Texel.

		Salt tolerance	**Salt tolerance**	
Crop	*Latine name*	*According to FAO reference*	*According to Saline test farm*	*Remark*
Sea cabbage	Crambe maritima	no data	tolerant	no halofyt
Beachbeet	Beta maritima	no data	halofyt	even grows on seawater
Lucerne	Medicago sative	moderate sensitive	moderate tolerant	
Honey lucerne	Melilotus officinalis	moderate tolerant	tolerant	
Seldery	Apium graveolens	moderate sensitive	tolerant	
Chicory	Cichorium sp	geen data	tolerant	
Carrot	Daucus caraota	sensitive	tolerant	difference observated between crops
Barley	Hordeum vulgare	tolerant	tolerant	difference observated between crops
Onion	Alium cepa	sensitive	moderate tolerant	difference observated between crops
Cabbage	Brassica oleracea	moderate sensitive	tolerant	difference observated between crops
Potatoe	Solanum tuberosum	sensitive	tolerant	difference observated between crops
Strawberry	Fragaria sp.	sensitive	tolerant	difference observated between crops.
Radish	Raphanus sativus	moderate sensitive	tolerant	
Lettuce	Lactusa sp.	moderate sensitive	tolerant	
Wild Rucola	Dipoltaxis tenuifolia	no data	tolerant	
Rapeseed	Brassica napus	moderate tolerant	tolerant	
Sugarbeet	Beta vulgaris	tolerant	tolerant	
Spinach	Spinacia oleracea	moderate sensitive		

Table 2.: General layout according to brochure of Saline Test Farm Texel. Only for Rapeseed and Spinach has a lower salt tolerance being signalled. All other crops were more salt tolerant than assumed. Source: Saline perspective, end report (2015).

Interesting to know that these changes in salt tolerance shown in the above table can have for water management enormous consequences which can involve millions of euros because this data has been used in freshwater models to underpin the Dutch water management.
The Texel Saline Farm research showed that this validating of salt tolerance has high priority and needs test location-based evidence. An example of change in costs for the Frisian situation.

Waterboard	Crop revenue on drainaged parcels, calculated with the current salt tolerance function	Crop revenue on drainaged parcels, calculated with corrected salt tolerance functions	Change in the revenues, caused by calculating with a corrected salt tolerance function
Wetterskip Fryslan + Wadden isles	89 125 048 euros	93 484 960 euros	4 359 912 euros

Table 3: Indicative figures of effects of use of salt damage functions for drainage of crops which are more tolerant than the damage functions which were used in 2013 in the Netherlands. The calculated agricultural damage decreases and the figures diver regionally. This was the underpin for calculation BRP 2010; card salt content surface water 1989; projected on the year 2050 W+ (warm). Source: Saline Test Farm Texel, 2015).

The test results also show that the assumptions where in many cases not correct. It is tricky also for farmers because it can make a difference for crop planning. Although the market is not ready, yet the saline circumstances will continue. In the Frisian Groundwater Study of this year the forecast is made that salinization will continue to increase land inward.

For this research a file has been made where the salt tolerance of the crops in the area has been determined. The following table has been used as reference, Roest et.al (2003). They present damage percentages per crop by use of rainwater. This is surface water, and this means it says nothing about the situation in the ground. If irrigation water is becoming to salt because seepage is rising it cannot be used anymore for that function. If there are no other possibilities there will be damage on drought (Delta fact, brakke kwel Stowa). This is relevant because in the pilot area irrigation is needed in times of drought and depending on the ‘Lake Ijssel inlet and the flushing. If this has been stopped because of prioritizing in times of drought there is no fresh water available and no alternative.

Underneath the table of Roest et.al. can be found. This table is relevant because most crops are irrigated.

Damage treshold		Damage function
Crop	**mg Cl/l**	**% loss of yield per mg Cl/l**
Potatoes	202	0.0610
Grass	962	0.0294
Sugarbeet	1288	0.0212
Corn	217	0.0343
Wheat	1288	0.0218
Fruit trees	171	0.0991
Flory culture	101	0.7086
Vegetables	245	0.0591
Horticulture	356	0.0527
Flower bulbs	41	0.0683

Table 6. salt tolerance per crop type for rainwater (Roest et al, 2003)

The second column shows the yield reduction when Chloride content is coming above the damage threshold. According to recent research the dividing into salt tolerance groups should be extended into *four* instead of *three* "Analyse zouttolerantie op basis van bestaande gegevens", WUR (2016). Then there will be an ordering similar as the table of the saline test farm Texel as showed at page 36, 37. A common used table also used as underpin for this research is the table at page 19 of the report of Stowa publications (Bakel en Stuyt, 2011). Because of authors right it cannot be copied and referred to: https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202000-2010/Publicaties%202005-2009/STOWA%202009-45.pdf

According to this table sugar beets and grains have the highest salt tolerance. These crops are best resilient towards saline irrigation water. Flower bulbs have a low salt tolerance which means that damage will take place when they are irrigated with water with a high Chloride content. This makes that fresh water for flower bulb companies has another meaning than for agriculture (delta fact, Stowa). Though potatoes are next to flower bulbs sensitive. The table shows that grass has a high salt tolerance. Because on grass mostly cattle are being held it is important to distinguish that dairy cattle are more sensitive because of their need of moisture. Above a concentration of 4854 mg Cl/l it will become problematic (Acacia Water, 2009. As some measurement suggest changing functions this is something to consider and is not applicable everywhere. This is also a part of the answering of sub-question number 4. Besides that, salinization will not be solved and reduced.

Chapter 4. Who are involved?

Introduction

To have an overview in who are involved in the problem of salinization sub-question 3 and the relation between water management institutions, the agricultural sector and society an ordering has been made and all will respectively be described and discussed.

4.1. The agricultural sector

De scope of the agricultural sector regarding salinization, the problem in this research, will be mainly directed towards water management.

4.1.1. Water use in the agricultural sector

The agricultural extractions are connected to climate circumstances like rainfall and evaporation. These can vary from year to year. Besides, there are differences in volumes during the grow season which is here from April until September. The extraction is mostly in deeper layers than those of drinking water facilities. The graph underneath shows the water use per sector. Agriculture is her not the main user.

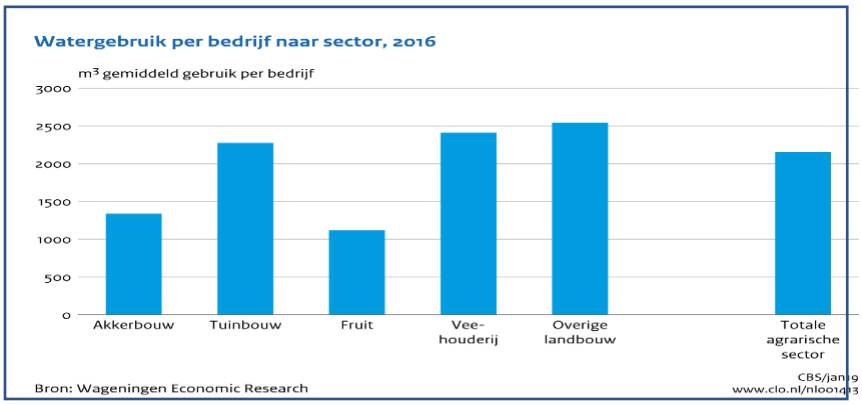


Fig. 9.: Water use in the agricultural sector in the year 2016, WUR

In the agri- and horticulture sector drinking water is used for cattle and the cleaning of stables. Also surface water is used for irrigation of crops. Especially the amount of water used is determined because of weather circumstances. In dry years it is obviously more than in regular years (Van der Meer, 2016). In dry years there is a higher demand for suitable water for irrigation and the flushing of salt.

In dry years the Province can decide on an irrigation stop. This implies the flushing of fresh water out of the 'Lake Ijssel' is banned. Flushing is a measurement to regulate salinization. Sub-question number 4. is partly answered by this. The northern Provinces depend on the 'Lake Ijssel' for fresh water supply.

Fig.1: Dutch Government, "Kenniscentrum Infomill"2019

To have insight in the use of water the table of WUR underneath gives more details.
Wageningen Economic Research provides data to CBS regarding the water use in agricultural sector

	Domestic water	Rain water	Groundwater (irrigation)	Surface or-groundwater (irrigation)	Surface water (irrigation)	Surface and or groundwater for cattle	Total
2001	50	0	23	8	12	39	132
2002	50	3	23	8	12	38	134
2003	57	6	101	22	32	38	256
2004	50	4	23	9	13	38	137
2005	47	3	24	6	6	36	122
2006	46	1	62	12	15	32	168
2007	46	3	19	9	9	33	118
2008	44	2	19	8	8	36	116
2009	47	2	39	8	6	37	140
2010	44	2	54	12	14	40	166
2011	43	2	60	0	19	38	162
2012	39	1	18	1	3	37	99
2013	41	1	53	-	13	39	148
2014	42	1	30	-	10	41	125
2015	43	1	49	-	19	37	148
2016	43	1	28	-	10	38	120

Table 8. Water use (in mln. m3), 2001-2016, Wageningen Economic Research 2018-105.

Agriculture was a long time not interested in high groundwater level but also not aware of salinization. Damage because of too much water is also a Climate problem to be considered. Also, for cattle outside too much water and with higher temperature than 10 Degrees Celsius the risk of diseases on hoofs increase. At clay or peat grounds risks of water damage, damage on grass can also mean lower yield. Proper drainage and moisture supply are needed for grass production and efficient use of fertilizers. Better grass gives for example lesser risk of parasites on cattle (WUR, 2002). However, lowering of water level is increasing salinization (Dufour, 1998). All factors must be considered and organised in water management.

4.1.2. Development

During dry Summers like in the years 1976 and 2018 salinization was a problem. Although the 'Lake Ijssel' is for the Frisian (but also other northern provinces) agricultural sector very important there had been an irrigation stop here and because of that damage.
The dependency of the 'Lake Ijssel' was pointed but also the problem of water quality which decreased because of the lack of precipitation and evaporation.
It is dramatical to see how crops are lost during extreme weather circumstances and is sustainable food production very important. For the agricultural sector it is important to know how much fresh water is available for the growing season. On the other hand, we know currently that agricultural sector contributes to Climate Change effects but is also vulnerable for the consequences of Climate Chance. To contribute towards solutions of both problems the transition in agriculture is needed. This is of course not only here needed.

Food safety and water management needs to be consistent. The demand for fresh water will increase if the autonomous salinization will increase. Water safety as protection towards sea is not dealt with here but of course crucial.

The soil in the northern western part of Friesland is very suitable for so-called 'open ground' cultivation. The agricultures have international a good reputation because of high value products. To maintain this status a combination of measurements and availability of fresh water is essential ('Spaarwater', 2019). Flushing and inlet of fresh water from the 'Lake Ijssel' is until now the way to deal with salinization and regulation method in the northern Provinces.

4.2. The Frisian Waterboard

The Frisian waterboard 'Wetterskip Fryslân' is the operational organisation and responsible for the water management regarding surface water. Some small groundwater issues belong to their tasks. The guardiancy of pumping stations, flushing, water level and water quality are the main tasks. The waterboard has a board were also users are represented. It is the oldest democratic institution of the Netherlands. Citizens, farmers and industry pay waterboard task. Recently, the discussion is going on if agriculture should not pay more for water. The OESO made in her report in 2014 a critical remark if the current system is enough for financing in the future.
For the costs of flushing, part of this research and part of the CBA was paid in the area close to the pilot between 2,30 – 3,00 euro per ha. for water inlet and estimated for irrigation an average of 70 euros. (App. IV).

If an agriculture enterprise suffers from damage because of water level guardiancy they can based on the 'disadvantage rule' ask for compensation. The waterboards must operate strategically in the situation where freshwater availability decreases. It is not sustainable to extend the current inlet of fresh water. Waterboards must show in the framework of Delta program Freshwater, how much water is available and used efficiently in relation to Climate Change and future demand. Climate Change and salinization ask for a controlled approach and dividing. Risks of freshwater shortage and salinization are studied to make further agreements on responsibilities and solutions ('Spaarwater', 2019).

Furthermore, the waterboard has an own water plan in which goals and ambitions are mentioned. Soil subsidence and sea level rise are touching on the tasks of the waterboard. The institute has a statement towards gas-mining and is against broadening of this practise. Firstly, because it is in contrast with the energy neutral goals and secondly because of the negative impacts on salinization and intrusion of sea which is already a fact and not solved yet ('Wetterskip Fryslân', 2018). The chosen pilot area in this research is in the water management area of this waterboard. For a measurement like 'SeepCat.', the topic of this research to be assessed, the collaboration with 'Wetterskip Fryslân' is required.

To have an instrument in the water management system the Frisian Waterboard has a Chloride map on her public website which is monitored at least twice a year. If possible, employees will take care of flushing by operating of pumping stations to mitigate salinization (see next page).

The Chloride content is calculated by measuring of EGV (= electric conductivity of water) of the surface water (website 'Wetterskip Fryslân').

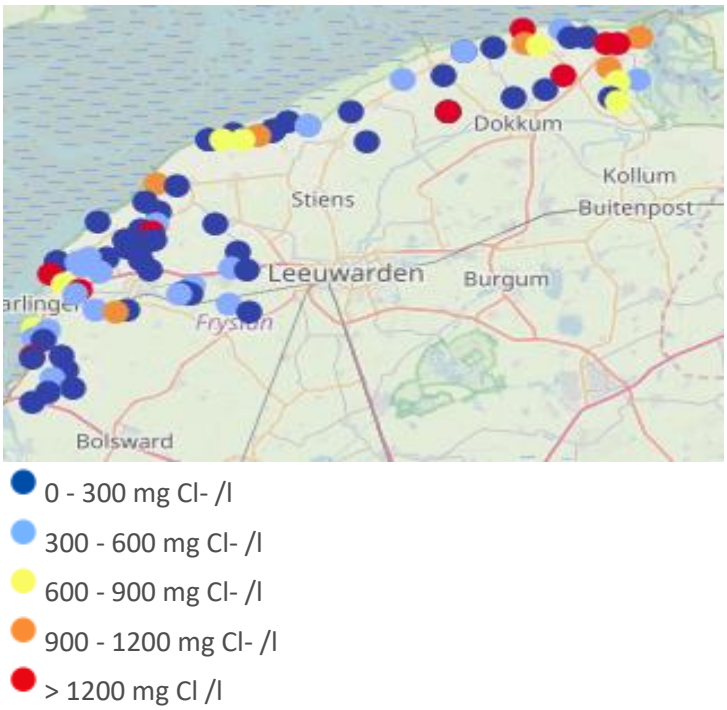


Figure:.8. Chloride content map, 'Wetterskip Fryslân' website, 2019

More background information can be found by pushing the button under the map of the website of 'Wetterskip Fryslân'.
The ordering of the several Chloride contents are similar as the classification of water based on Stuyfzand (2007) to know: fresh/brackish/saline.

4.3. The Province

Without going to much in detail because the Province is an institute with many departments the most important and for the future relevant policy aspects will be mentioned. The 4th "Waterhuishoudingsplan" gives detailed information on roles, tasks and responsibilities which relate to water management. The attention is on enough, clean and water safety. The Province is ending responsible concerned water extraction and the translation of national policies to region. The Province has operational tasks towards groundwater like permission of groundwater extraction for Cold and Warmth storage for industry and is responsible for maintenance of the measuring grid for groundwater (see underneath picture), KRW direction, recreation and nature areas but is not dealt with here. The Province is not the water guardiancy in the framework of the Water Law. These are 'Rijkswaterstaat' for the main water system and the Frisian waterboard, 'Wetterskip Fryslân'.

The groundwater network is an important instrument to control the levels and one of the tasks organised at the Province.

Picture 10: A. Venema, Province of Friesland, measuring groundwater level in ‘Finkum’, June 2019

A graph related to groundwater (fig.8) shows for example the relation between land reclamation in the North East “polder” and the lowering of the groundwater level in the Province of Friesland. This shows that water and land systems are not separated, and the underground situation should be taken into consideration.

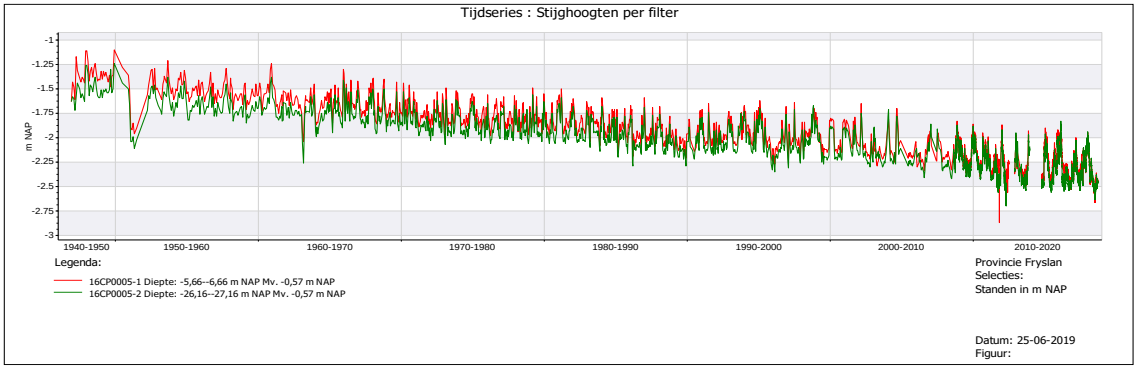


Figure 13: Location ‘Slijkenburg’, Province of Friesland

As mentioned in the previous paragraph the “Omgevings Wet” will shortly being implemented. The in 2009 established Water Law is implemented in this new law. The Province made a design together with representatives of the Frisian Society and the Frisian waterboard. The vision of the Province will be organised in tasks; solutions will start with consciousness and implementation of own policy. The ambition is directed from 2030 to 2050. The tasks are:

1.: Liveable, vital and infrastructure
2.: Energy transition
3.: Climate adaptation
4.: Strengthening of biodiversity

The vision is being followed by execution and reaching of the goals
Salinization has the attention of the Province regarding the protection of drinking water and the quality but also towards the waterboard for the concern of the in this research related coastal clay area.

For extractions of 150.000m^3 per year is the waterboard responsible. This is relevant for the pilot in this research because of permission to extract saline groundwater. The estimate is 10 m^3 per well per hour and 12 wells, gives 120 m^3 per hour = 43.800 m^3 (based on 365 days) per year*) (personal announcement of W. Elder
horst, 2019). More about the pilot can be found in Ch. 7.

4.4. Research institutes

Research institutes have more and more a role in the Climate Change process. Mostly co-creations are established of which the most important in the northern region are named. The attention is on knowledge building, awareness raising, innovation and solutions, business cases and involvement of the younger generation. For agriculture the transition towards nature inclusive circular sustainable agriculture is currently a hot item. The following institutes are of importance in relation towards salinization the main topic of this research.:

'Deltares'
'Acacia Water'
'Wadden' Academy ('International Salinization Congress', September 2019)
WUR
RUG
'UTwente'
'Wetsus'

4.5. Agricultural organisation

LTO is the most important organisation in northern Province Friesland which defends and negotiates the interest of agricultural sector.
The Delta plan Agricultural Water Guardiancy, DAW, is an initiative of LTO, on the invitation of the government. The goals are to contribute on the water tasks in the agricultural region and realise a strong and sustainable agriculture. To reach this the collaboration between agricultural companies is needed, but also the collaboration with waterboard(s) to solve the problems related towards water. Water quality is under pressure in times of drought as mentioned before but also the use of pesticides and disposal of water (saline). According to Mrs. T. de Vries, is salinization not a change but a serious threat (Dec. 2018). There are disputes because of some project plans with nature areas but to her opinion the Province thinks too easy about the way farmers should treat salinization. The discussion is on the space within the dikes. The new "Omgevings Wet" will have influence on this. Further is Mrs. De Vries willing to work towards circular sustainable agriculture, which is of importance for the whole water matter, but she remarks that it should remain workable for agriculture.

4.6. Consumer

Finally, the consumer as buyer of agricultural products but also as user of water is of importance for the sustainable future of agriculture and water management. The market is not yet ready for saline farming learnt the bankruptcy of Saline Farm Texel. But also, for the whole transition in agriculture the consumer can decide on buying sustainable products. The more consumers will do the cheaper the products will become, and the change will go faster. The costs of fresh water will be reckoned in price of food in the end. The water and foo(t)d print of the consumer is of importance not only for the domestic market but also for the international market. In every product has energy, water and resources been used. We cannot dump our waste to developing countries and we cannot import waste as well.

Scandals in agriculture with manure and others have putted a negative image on agriculture but not everyone is to blame and to that extent. Farmers have a lot of investments in their companies and are restricted by that and market as well. Globalisation has changed the market and import products are often cheaper. By supporting our local produced food, customers can sustain agriculture. The whole sale market has also a role and can give some extra on top for sustainable products or guarantees just as in Ireland or has been done with the milk price.
Organic milk is affordable and by buying this we help agriculture and the Climate and ourselves. The organic sustainable food market is ready according to prof. Schulte (WUR, 2019)

Picture 11.: saline farming on Texel, 'Zilt Boerderij' Texel (2018)

To summarise and answer sub-question 3 all actors have influence on salinization. It touches up on the Food-Water-Energy-Nexus. Although the problem is concentrating on agriculture is also water management involved because of water quality and quantity. Research on the extent of salinization and damage can also be influenced by agricultural practises but will institutes be needed for some facilitation, coordination and knowledge certainty and providing of hard data and teaching programs at schools. The Delta programs give direction and the new "Omgevings Wet" in which the Water Law is embedded and the framework. The ambitions and goals of the Province and waterboard together with stakeholders and other institutes decide on the policy and implementation of measures also regarding salinization. Recently, farmers showed by protest marches that Climate problems touches them although the sector must change but this can only be done gradually. Dependency of fresh water will remain important and facilitating as well and Climate Change impacts must be solved together. There is a tendency that the incomes of farmers decline (agri-food scan 2019) which has consequences for the investments they can realise. Sustainable practises can however be beneficial for farmers as well in the long term. A strict water policy and practise will accompany that. Cleaner water, vital soil, higher yield. Tax reduction and subsidies or guarantee for sustainable practise will give the support in the right direction and consumers must do the rest.

Chapter 5: Legal framework and policy

Introduction

In the previous sector on actors already institutions have been described. Additionally, in this paragraph will be analysed some relevant policies and laws. This is relevant to answer sub-question 4. It gives insight in the direction towards water related problems and developments in future governance. Salinization is a problem which should be solved in co-creations between agriculture and water management. The history of law and regulation will not further be deepened here. The future in the context of Climate Change problems is relevant. It is obvious that the existence history as explained in the first chapters and the current Climate Change development have influence on the water system. Salinization needs and integral approach. Law and regulation will organise this.

The 'Water Law' established in 2009 is a contraction of eight laws into one. The 'Water Law' arranges the guardiancy of surface water and groundwater and improves the connection between water and spatial planning. Besides that, the Water Law is a contribution to the goals of the government, like establishing a decrease in regulation permit system and administrative burden. Until 2021, when the new "Omgevingswet" will be implemented, the 'Water Law' is rule. Waterboards and Rijkswaterstaat have a duty of care.

Water management is not a matter of one party, but a cooperation of all board layers in the Netherlands. There is a collective responsibility, where tasks are being done together, co-ruling. This means that a clear stating of responsibilities of the different involved governments is important. In the Water Law this has been done as follows:

the Government is responsible for the national policy framework and the strategic goals of the water management in the Netherlands and for measurements which have a national character (i.e. transport, water safety, infrastructure, recreation, fishery, agriculture, industry)

- The Province is responsible for the translation of this to a regional level. There has the Province operational tasks for the part of the groundwater management. The Province is not a water guardiancy in the context of 'Water Law'.
- The water guardiancy (the waterboards for the regional water systems and 'Rijkswaterstaat' for the main water-infrastructure) is responsible for the operational water. The water guardiancy decides on the conditions to realise the strategic goals, decides on the concrete measurements and will execute these.
- The Council has only a few tasks, involving rain- and groundwater care duties. The care for wastewater system belongs also to the Council, but this task is organised in the Law Environmental Guardiancy ('Rijksoverheid').

Furthermore, next to the above-mentioned plans on water the European KRW, on water quality is leading.

The national Delta Program, the Delta Program Fresh water, the Delta Program Agricultural water Guardiancy, the Water Law and future "Omgevings Wet", the Provincial 4th 'Waterhuishoudingsplan', the regional Waterboard Plan, and Council Plan will all play a role.

The end responsibility for the water concern in Friesland is nevertheless the Province.

The essence of the coming “Omgevings Wet’ (2021) is that issues regarding Climate Change, ‘energy transition’ and ‘circular economy’ follow an integral approach to avoid governmental compartmentalization.
In practise it appeared that regulation conflicted with each other and blocked progress. Initiatives had not, or been initiated too slow, while these matters mostly correlate and need to be addressed and solved together (VNG, 2019).

The “Omgevings Wet” is a framework. It has a stated general frame and will in so-called ‘AMvB’ (general measurements of governance) the frames been worked out further. All measurements have been collected in one rule with *four* ‘AMvBs’. The Water Law is part of this. An ‘AMvB’ has as advantage that the procedure along which it must be established is more simplified than the one in the Law (in formal sense) (Province, 2019). It will give more room for concern and accuracy to realise initiatives in which problems like Climate Change can be tackled and organised in co-creations between government and citizens (film YouTube VNG).

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Chapter 6. Other measurements and (ongoing) projects/research

Introduction
To answer sub-question 5 of this research a choice has been made between some measurements which are dealt with in the Province of Friesland so far or in the northern region or coastal regions and because of that comparable. Firstly, some projects will be described and afterward some technical innovative measurements.

6.1 (Ongoing) projects

6.1.1. 'Spaarwater'

The Delta Program for Fresh water has the focus on the 'Lake Ijssel' region and the sharing of this water but also to increase the independency of the 'Lake Ijssel' for flushing for agricultural use. ('Spaarwater', 2019).
The project 'Spaarwater' is focusing since 2013 on the safeguarding of freshwater sources by increasing the freshwater supply and decreasing the freshwater demand. This has been done with measurements like:

6.1.2. Own water supply with underlayer storage

With an own water supply in the form of underlayer storage of freshwater the farmer can become completely self-sufficient. The fresh water is through drainage captured in the parcel, thereafter, stored in the deep underlayer and made available for the use during the growing season.
The success of underlayer storage lays in the possibility of a) the capturing of enough fresh water, b) the possibility to store water in the deep underlayer and c) the winning back out of the underground. Besides that, it is important, to measure the needed water demand, and if the supply adequately connects.
Depending on the water demand also with a lower win back efficiency there can be achieved enough freshwater for the project area with salinization risk. This varies from 25 to 50% and makes the technique promising in the project area of "Spaarwater".
Underlayer storage leads to less disposal of salt, nutrients and crop protection products via drainage to the surface water. It reduces the peak disposal of rain and leads to an inlet reduction of 11%, without negative consequences for the water quality.
Infiltration and extraction of drainage water in the underlayer results within a multiple system to the breakdown and storage of the plant protection products through soil transport. Research shows that there are not or a reduced change or decreasing risk effects when using underlayer storage. For plant pathogen bacteria like 'Brown rot', is the contamination risk minimised because there is not made contact or is made use of surface water.
There is not a complete alignment on existing regulation for licensing for underlayer storage. To cover shortages in the current regulation and licensing it is to be recommended to use a risk approach in the application ("Spaarwater". January 2019).

6.1.3. Anti-salinization drainage or system drainage

This involves a collection of drainage techniques which are used to solve salinization and increase the fresh water supply in the underground while disposal on the parcel remains. This is achieved by making use of the distance between drainage pillars, the level of the installation and to optimize the

level of disposal to the groundwater system. The disadvantage is the so-called “Waterbed effect “where salinization in another parcel not in the drainage area can increase. In underneath picture has a result of anti-salinization drainage been illustrated. (Spaarwater, 2019).

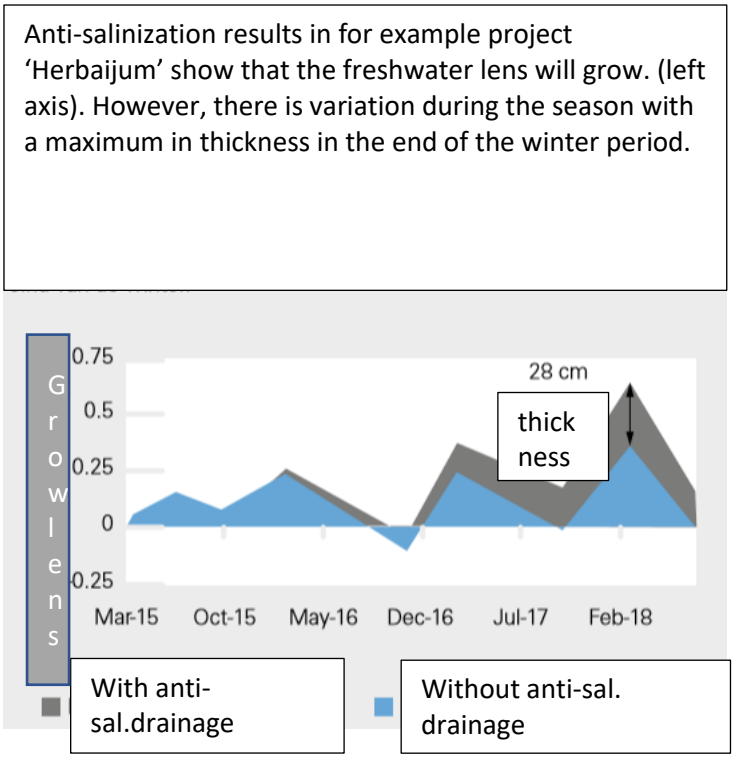


Table 7: results ‘Spaarwater’ at ‘Herbaijum’, ‘Spaarwater’ 2019

6.1.4. Economical use of fresh water

Water efficient irrigation systems like drip -irrigation and sub-irrigation decrease the freshwater use of the farmer. Besides are fertilizers efficiently applied which means a saving in costs. The use of non-use of these systems depends on the type of soil, land use, the average low groundwater level and the iron and salt content of the irrigation water. The traditional way of irrigating with a water cannon and divider is under Dutch conditions low because of evaporation. In the “Spaarwater” project is assumed that economical use of fresh water is possible, and a water effectivity can be reached of 85% if drip-irrigation is applied. Besides 40% less Nitrogen and 40% less Phosphorus flows away into the soil moisture. By applying drip-irrigation in underground can 50% less Nitrogen and 40% less Phosphorus being realised without crop reduction because of damage. The farmer can in this way save costs on fertilizers and control the process and contribute to water quality (Spaarwater, 2019).

6.2. Seasonal storage

By creating and increasing the area for surface water, where a flexible level can maintain, can winter surplus of water being stored. This water can in summer being transported to brackish areas in a “polder. In the Province of North Holland are on a small scale old beach walls along the coast being used for such storage. In the Province of Zeeland old creeks are being used where natural fresh water is available. Research is been done on this (Stowa, 2009). It might be possible that in Frisian parts such walls or places can be found for storage.

Just as a suggestion, on an old picture a sand creek in the ‘Snekermeer’ has been noticed, but depends on under layers if such a solution for storage of fresh water is applicable here.

Picture 12.: H. de Boer, “*De Gravinneweg, Sneekermeer, bij den lagen waterstand in Augustus 1911*”.
Fresh water can also be stored in deep aquifer (with brackish groundwater), by injecting of fresh water through pressing wells. On a small-scale water can be stored in freshwater lenses on the parcel (Zoetwateropslag Zeeland, 2019).

6.3. ‘Boeren Meten Water’

Not directly as a measurement to mitigate salinization but as an instrument to have control the project “Boeren meten water” is being started. This gives with measuring equipment more insight in the salinization situation also in the pilot area. During this research the information meeting in ‘Holwerd’ has been visited where farmers shared their first experience. Because of a subsidy out of the POP3 program can more farmers join and gain knowledge and control over the situation in their parcels. Salinization can move under the ground. Data is needed to detect where salinization occurs and is also important to make reliable calculations on a regional level.


donderdag 27 juni 2019

LC fryslân

cultuur&media 34
radio&televisie 38
uit&service 40

fryske marren
Kleine dorpen mogen toch, op maat, uitbreiden p.26

nalbeid fries
Staat er straks ‘Plysje’ op Friese politie-auto’s? p.31

Aquapin meet verzilting diep in akkerbouwgrond

Boeren kunnen gegevens 24 uur per dag afl ezen van hun app

simmerdeis

De natuur in met half mens, half boom p.33

Unesco: niet boren in de Waddenzee

Opening Lelystad verder uit zicht

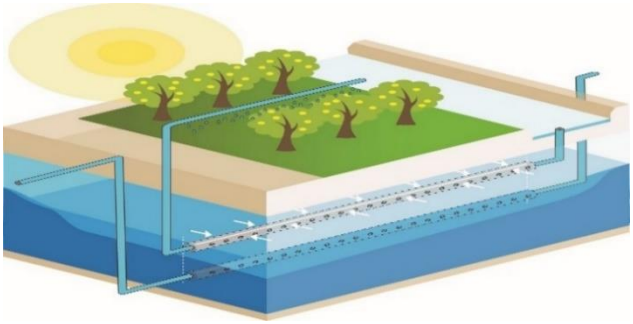
meer nieuws > www.lc.nl

- Picture 13.: “Boeren meten water, “Leeuwarder Courant”, 2019

As mentioned before for the project “Boeren meten water” is a subsidy available at the Provincial agricultural department (POP3) and are farmers encouraged to measure their parcels and follow the development and gain important data.

6.4. Other technological option for pilot area

6.4.1. The Fresh maker



Picture 14: 'Deltares', project GO-FRESH

The fresh maker infiltrates surplus fresh water via one or more horizontal wells in an existing freshwater lens. With one or more horizontal wells will at the same time saltwater being extracted which gives room and to prevent that fresh water will float in saltwater. In this way the freshwater lens will grow and kept in a zone of some tens of meters around the wells. In summer can shallow wells being used for the extracting of the stored fresh water. This can immediately be used for drip irrigation or the gradually supply of basins. The expected volume per set of horizontal wells (1 deep, 1 undeep) is 10000m^3 a year. The expected flow rate (='debiet') of which fresh water can be delivered is at a minimum 10 m^3 per hour (Fresh maker, Kennis voor Klimaat 2013). The growing of the freshwater lens is going fast. From 9 to 13 metres a year ('Freshmaker', 'Kennis voor Klimaat' 2013). The 'Freshmaker' is very suitable to apply in an area with more farmers and to implement as an 'area 'Freshmaker'. Because the Fresh water remains, the saline water can be kept deep in the underground similar like the 'SeepCat.' For the 'area Freshmaker' has been developed some organisation and a business case (Deltares, 2019).

6.5. Research

6.5.1. RUG

-RUG plant/crop physiological research done together with potato farm companies in the Province of Groningen can be useful for Frisian farmers as well.

Several selection methods are developed where potato sorts can be modified based on their root characteristics. Specific root characteristics and the underlaying processes are identified where new sorts can be developed which need less fertilizers and water and are resilient to abiotic stress like drought, flooding and salinization. These new sorts with a strong reduced risk for production- and yield lost contribute towards Climate adaptation.

Picture 15.: RUG research together with farmers in the Province of Groningen (RUG, 2019).

6.5.2.RUG and WUR

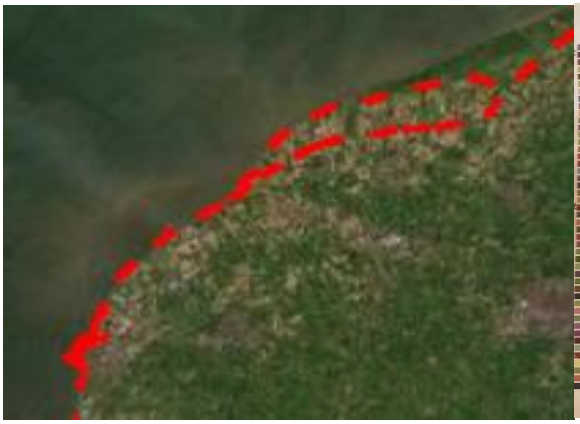
Recently, July 2019 Wageningen University and Groningen have announced to work together in sustaining the transition of so-called “nature-inclusive-agriculture”. The northern Provinces are designated were pilots and test areas will be formed for sustainable agriculture.

Chapter 7. The pilot area and state of salinization

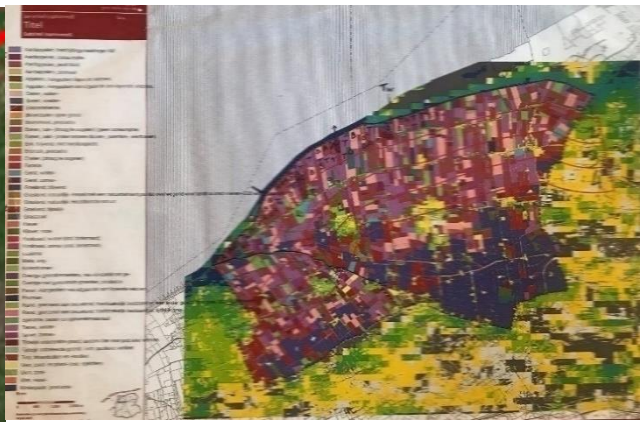
7.1. Pilot area

To designate a suitable area for the research project the region between ‘Westhoek’ and ‘Zwarte Haan’, a stripe along the ‘Wadden’ coast with a length of 10 km had been chosen. This answers sub - question 7. The pilot details can be found in the financial overview in Ch.8. The region has a high number of farmers which produce high valuable crops on the fertile sea clay. The history of the Frisian north western area is dealt with in Ch.3. An example of the profile of the underground can be found at Ch.3, p. 28. A list with all relevant measuring points was made with coordinates based on information from “Dinoloket”, (=geographical database) and to be found in App. III.

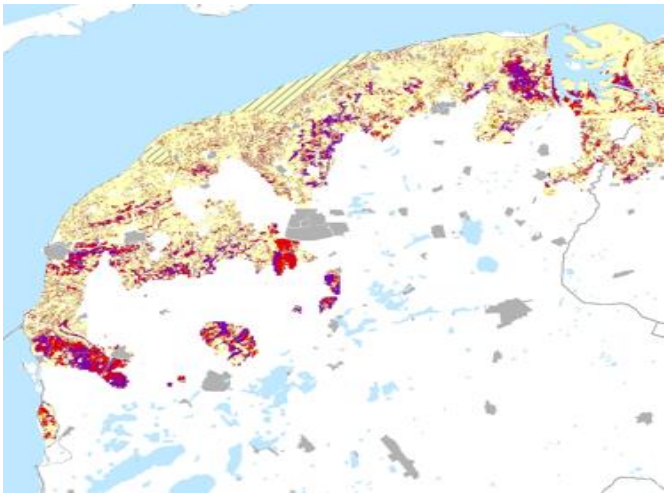
On underneath pictures is part of the area illustrated. The picture left shows the coastal line and is from the legal ownership of the waterboard, who is owner of the dike. On the picture right are the parcels and is out of GIS. An ordering has been made from 1 km to 4 km land inward. Calculation of the consequences of salinization and the linear relation has already been mentioned in Ch.3. App. VVI gives all results. The recently presented ‘Friese Grondwater Studie’ (Sept.2019) announces an increase of salinization as a result of Climate Change and autonomous processes. For detailed causes and the nature of several types of salinization is referred here to Ch. 3. of this research.



Picture 16.: pilot area and owner dike Wetterskip Fryslân



Picture 17.: pilot area in km zones, GIS, Province of Friesland



Picture 18: salinization map, Acacia, 2017

7.2. Geological aspects of the pilot area

It is for the test pilot import to know how the underground looks like. This is among others needed to decide how deep the pillars should be installed. In doing so this will generate tailor made design which contributes to efficiency and saving of costs. The geological layers are described as formations. A detailed description can be found in the 'Friese grondwatersysteem beschrijving' (2017).
The most important geological formations are described with a Capital letter and abbreviation. In the right-side of the picture is the location of the profile been showed. The formations are explained in table 4. This answers sub-question 9a.

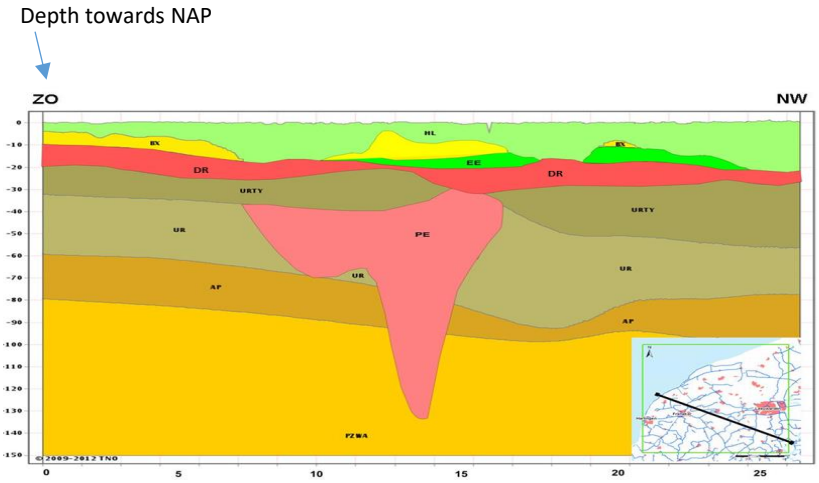


Figure 11: "Surface" (= Maaiveld), 'Friese grondwater systeembeschrijving'

Unit	Abbr.	Deposit	Environment	Main ground content
Holoceen	HL	Fluvial	Coastal	Sand, clay and peat
Boxtel	BX	Eolisch	Local rivers	Sand, very fine until rough and loam
Eem	EE	Undeep marien	Coastal	Sand, (fine until average rough) and clay (shelves)
Drenthe	DR		Glacial	Lullaby
Urk-Tynje	URTY	Fluvial (Rhine)		Sand (average rough until very rough)
Peelo	PE		Sub-glacial and melting water	Sand (very fine until very rough) and clay
Urk	UR	Fluvial (Rhine)		Sand (average rough until very rough
Appelscha	AP		Fluvial (Eastern rivers)	Sand (average rough until very rough)

Table 4: Geological units and characteristics in the pilot area
'Friese grondwater systeembeschrijving, /* aanvulling Dinoloket'

The in the pilot available measuring points and descriptions are in App. III. The map is from 'DINO-loket'. The availability of permeability of these several formations and layers is much smaller. Mostly researchers must estimate by using knowledge and experience. When using ground water models, model calibrations will always form an important part of the research. However, in this research this is not yet been done. The description of the drill locations shows whether and at which depth sand layers occur. These sand layers are suitable to extract seepage water. The filters of the 'SeepCat.' well needs to stand on the sand layers. In App. III is for every drilling point mentioned at which depth sand occurs.

7.3. The agricultural sector and water management situation in the pilot area

Introduction

In general agriculture contributes considerably to global warming because of the emitting of gases. The sector with as well plant- and animal system produces CO2, N2O and CH4. At the same time agricultural systems are vulnerable for the effects of Climate Change and will without measurements the food production become under pressure. A transition of the sector is needed. In this paragraph some current developments are described to provide context to as well the CBA in Ch. 8 and the arguments which are related to decide on a technical solution like 'SeepCat.' and the purposes.

To address the problems of Climate Change new production methods are needed. At WUR, the so-called CSA (climate-smart-agriculture) has developed which tries to solve problems integral. As example, a better integration of land- and water system is needed to be ready for future Climate Change. CSA combines three goals 1) sustaining of agricultural production 2) adaption of agricultural and food security systems towards Climate Change. 3) Reducing of emitting gases in the agricultural sector. To mitigate Climate Change and to have the sector adapted for the consequences there must on several spatial scales, time paths, season to decennium being worked. Not everywhere is the impact the same but in general the sector must be made future proof and in balance with the eco-system. On many levels research has been done to try to control the negative effects of Climate Change on plant and animal level. That water management plays a key role needs no further explanation. It is mentioned that agriculture should adapt from a 'freshwater system' to a 'saltwater system'. However, this has large economic consequences especially in the region of this research project.

Agriculture in the northern western clay area is under influence of 'Wadden' sea and the intrusion but also because of the rise of seepage groundwater coming closer to the rootzone of plants. This is the case during drought. The need for flushing becomes bigger and must fresh water stop the saline but is also water quality of flushing water because of less supply and evaporation a problem.
The hydrologist of the Frisian waterboard states in here presentation of 2018 that flushing with fresh water, storage of rainwater and flexible levels are enough to control salinization. There are some problematic lower areas but there are other factors as well which are listed in Ch. 3.
The hydrologist of the Province of Friesland is looking for more circular approaches for the flushing water because of water scarcity in periods of drought like in 2018 but is also more sustainable.
The separation of saline and freshwater system needs attention as well which was stated at "Saline Futures Congress" in Leeuwarden (September 2019) and must new salinization be prevented which can happen because of this.

Some farmers in the northern area set up a collaborative initiative to cope with Climate Change problems (EcoLaNa, 2019). Mr. Van Sinderen of EcoLaNa has been visited during this research. By joining forces, they have room for as well livestock and agriculture activities like potato farming, innovative technology development like Methane reduction through innovative stable building and created biodiversity buffer land spaces for flowers, insects and birds. Biodiversity is needed as a natural pesticide. This farmer can see by the vegetation of plants in ditches if there is a salinization danger. This vegetation, for example "Zeebies", *Bolboshoenus Maritimus*. and "Egelskop", *Sparganium*, indicates that there is saltwater. Confirmation could be found by measuring the water with an EC meter. The results (App I.) show again the differences between ditches although relatively close and in the same area.
The farmer was conscious and worried about the future if Climate Change problems are growing. In the first place he as a farmer is involved and depending on weather and climate issues. In the second-place damage and loss has also an impact on the enterprises related to agriculture. Thirdly, this region has not a lot of alternatives and fourthly in the area has gas -winning being discussed. Industries are not typical here. The farmers have as landscape guardian role as well which was instituted in last decades (Agri-Food scan, 2018). The economic value of the crops is evident and alternative crops are not marketable yet and gaining the same revenues. Livestock enterprises or more common on other soil grounds but is a possibility. If the water quality is enough with a higher salt content needs further research. It can be imagined that for some products, e.g. baby-powder-milk/diet products, a higher Chloride content is not desirable and what means a higher salt content for the cattle? The picture of the situation described by this farmer is almost equal to the picture found in the so-called 'Friesland scan', a research (Agri-Food Scan 2019). The development of the region is of importance and farmers need proper solutions. The 'SeepCat.' can contribute towards this in the long term although flushing of water is cheaper until now and there is still enough water according to the hydrologist of Province.

However, salinization is not solved in this way and will come more land inward. The freshwater lens under the surface is not growing either to keep the salt under the ground. Integral smart solutions in cooperation with water management will have a sustainable impact on the region. If a pilot should be organised in an already established association of motivated farmers like the visited ones the maintenance costs and public money can be reduced by farmer's participating. Although some training will be needed (P. de Louw, 2019), it gives farmers next to consciousness and responsibility, control towards freshwater and in such way a cooperation between government and farmer and independency from the 'Lake Ijssel'. This region had in the drought period of last year because of prioritising regulation regarding 'lake Ijssel', and therefore irrigation ban, damage. A measurement like Seep Cat will give stability in coastal areas suffering from external salinization, suffering from more forecasted drier periods, and in the transition to sustainable agriculture it can be hold as prerequisites and will food production and quality be safeguarded. Water security and water quality are undisputable essential for the growing of crops. These values are hard to monetise but will be further dealt with in Ch. 8. (CBA). In situations where nature is being created and dikes will be forced (plan Holwerd aan zee) and generates a saline influence on crops and soil, the Seep Cat. is an accurate compensation measure. In the Province of Zeeland, the farmers are satisfied about it. This answers sub-question 7.

Intrusion of sea and sea-level rise is a coastal problem and agriculture is mainly impacted here.

<u>To summarize</u>
Which measurements or combinations must be decided on is premature. More knowledge is needed to have hard data on regional damage amounts, insight in salt tolerance of crops, accurate insight in where salinization is and to what extent and how it moves (unripe clay see Ch. 3). The new law "Omgevings Wet" will gain influence because an integral approach is needed to solve the problem of salinization.

Co-creations between government and farmers can give room for implementation of ‘SeepCat.’ as independency of the ‘Lake Ijssel’ is because of Delta Plan forwarded and water security and quality and food production in this way safe guarded.

In order to save costs but also to improve the eco-system and water quality it is important to have insight in the use of pesticides because of salinization. The risk is there that more pesticides will be used because the working of them will decline and salinization itself causes more change to have diseases because of the decreasing soil condition and must a vicious circle be avoided.
The measuring is a critical point because nowadays pesticides in intensive agriculture (in the pilot area) and flower bulb farming are thinned (Watervisie 2012, Province N. Holland).

It is very important to upscale biodiversity as a natural pesticide in this region like EcoLaNa did. This ‘best practise’ should be followed in the whole region. Between parcels have been made already extra biodiversity strips (EcoLaNa, Ternaard 2019). The circular agriculture policy towards 2030 will accelerate if sustainable products are produced and bought as stated before but is fresh water needed. Saline farming is not solvable yet (Bankruptcy, 2019). ‘SeepCat.’ can help to have background for the future and build on proper soil and its restoring which is needed to keep the salt in the ground, to store CO2 and use the quality of purifying of water and storing of fresh water. The areal of agricultural fertile land in this area contributes towards the economic position of the Frisian Province and the national income and food security. If sustainable products can be made the position of Dutch agriculture can be established and knowledge exported. The world is looking at the Netherlands (prof. Schulte, WUR, 2019). According to professor Schulte (WUR, 2019) the market for sustainable products is ready but circular agriculture can not only be left to the market. Facilitating/conditions are needed. Climate Change is not only caused by agriculture. Everybody has a responsibility, but it is guiding to a new world and better eco-system and contributes to solving of Climate Change and global warming in that way.

Chapter 8. 'SeepCat.'

8.1. 'SeepCat.' Technology

To answer sub-question 6. of this research the 'SeepCat.' and it's principles will be described and explored.

The 'SeepCat.' protects the freshwater lens which is threatened because of sea-level rise along coastal areas because the increased ground water pressure makes that the freshwater lens will shrink. A freshwater lens is a bubble fresh groundwater, which because of difference in density floats on saltwater. The 'Seepcat'. compensates the pressure and salinization will not occur. The 'SeepCat.' thus, protects the freshwater lens by catching the seepage. Once caught in pillars, the seepage is collected in small waterflows and being disposed at sea. The pressure of the saltwater on the freshwater lens will decrease. This will then not shrink and in right circumstances, even grow. The 'SeepCat,' name is a contraction thus of 'seepage catcher' to memorize. The technology exists of a series of vertical well screens which are placed approximately 15-25 meter in the soil of a coastal strip. (Deltares, 2016).
Small isles are vulnerable because they have a natural small thin lens but coastal areas where agriculture depends for irrigation purposes on fresh water will become vulnerable as well. Since in the Frisian situation the 'Lake Ijssel' becomes under pressure in times of drought and the policy is to become less dependent from the 'Lake Ijssel's' fresh water for flushing and there is a priority agreement during drought were agriculture is in category three, it is not unreasonable to research and surge for proper and reliable alternatives. The drinking water purpose is beyond the scope of this study but can be an issue in future since in the Province of Friesland new drinking water facilities have to be found/created.

8.2. 'SeepCat.' pilot in the Province Zeeland

In 2012 a so-called well screen was advised to mitigate the tidal effects in the 'Perkpolder' situated in the Dutch Province where the farmers use the freshwater lens for agricultural use during drought periods. The lens was because of the development of tides in the area, where the dike has been forced, coming closer to the new dike and became sensitive for salinization. The farmers feared shortage of fresh water needed for crops for now and future generation. 'SeepCat.' was implemented in a multi-million project 'Perk Polder' and costed more than 800.000 euros. The Provincial institution and Rijkswaterstaat were involved. These costs are excl. design of the construction, hydrological measurement and zero measuring. In 2010 the first initiative was taken to compensate the tidal effects which increased salinization and were caused through the building of the project and forced breakdown of the dike. The level of the sea is approximately 1 meter in the dis- "poldered" area. The solution is meant to compensate the farmers because of the economic loss they suffer and otherwise must been compensated by the government. This is the agreement.

<u>Installation</u>
The 'SeepCat.' was installed in 2015. The design of the 'SeepCat.' has been changed. In the beginning sand piles were suggested followed by vertical seepage pillars, and afterwards horizontal deep drains. During a second opinion the well screen had been changed back again to vertical seepage piles. Horizontal deep drains cause higher maintenance costs.

The working of the ‘SeepCat.’ will be explained underneath. The figure is because of translation purpose an adjustment of the original scheme of ‘Deltares’ (zeeweringenwiki).

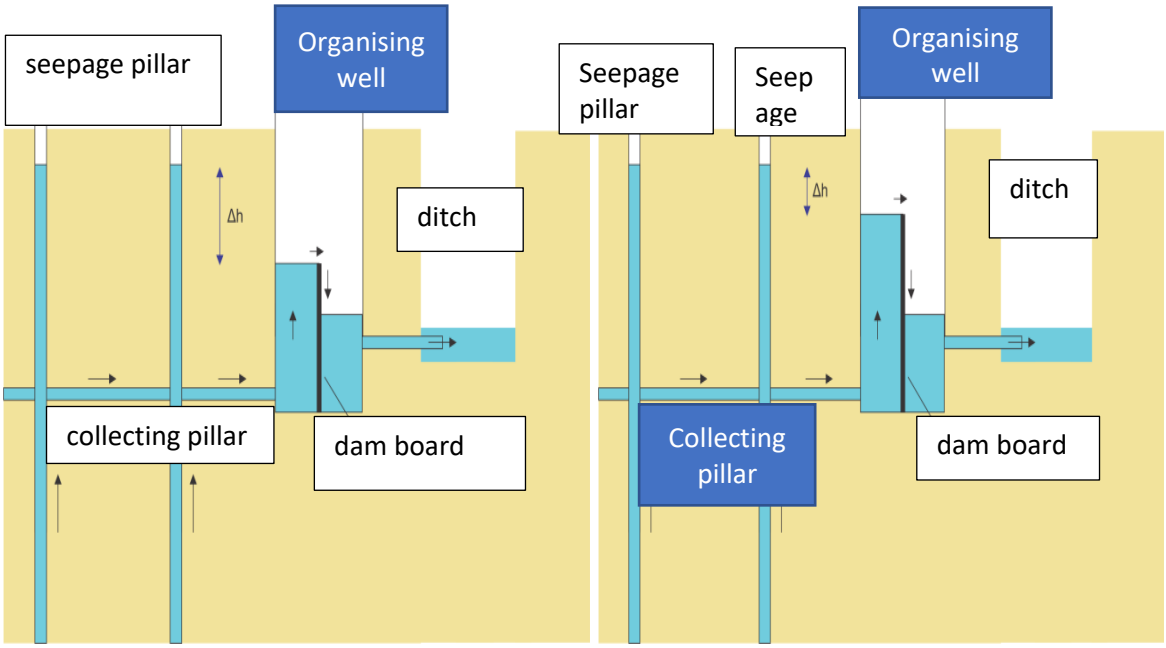
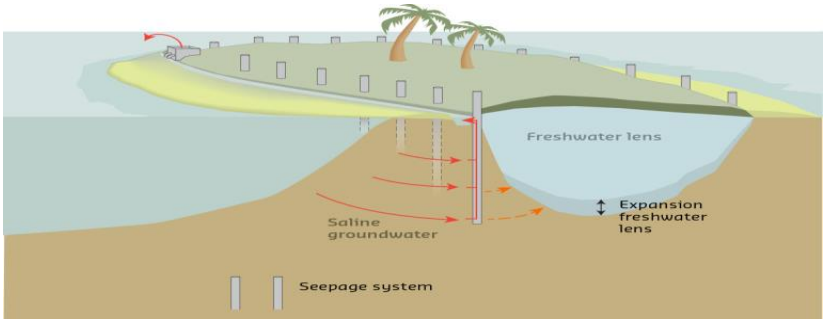


Figure.: 12, principle of ‘SeepCat.’, Deltares (‘zeeweringenwiki’)

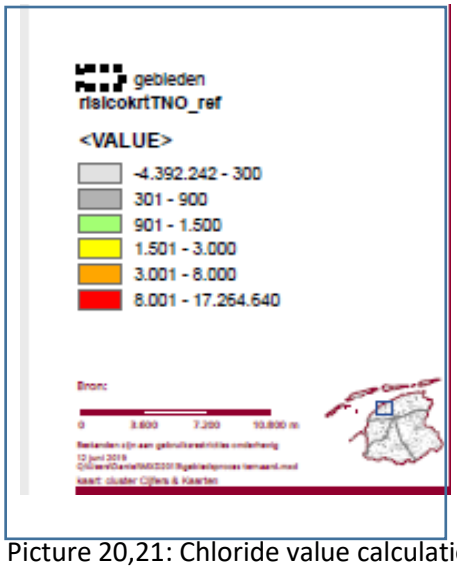
The schematic presentation (fig.12) shows the seepage facility and the underground relation of seepage tubes, which end in an organising well which disposes the water into the ditch. Δh gives the rise height difference between the rise height in the first aquifer (see list with definitions) and the stowed level in the organising well; the larger Δh, the more groundwater the seepage facility disposes. Δh can be influenced by changing the stowed level in the organising well; to compare situation in the left-side figure (low level, huge Δh, high disposal seepage facility) with the situation in the right-side figure (high level, small Δh, low disposal seepage facility).
The growing of the freshwater lens in times when fresh water becomes scarcer is a big advantage. A disadvantage is the saltwater which must be disposed. Depending on where the ‘SeepCat.’ has been implemented, it can conflict with natural brackish areas if seepage is disposed directly at sea or in ditches were no flushing with pumping station is possible or near and seepage is causing water quality problems (see SWOT analyses p. 79). On picture 19. the ‘SeepCat.’ is disposing water straight to sea (red arrow) but there are no dikes to consider.



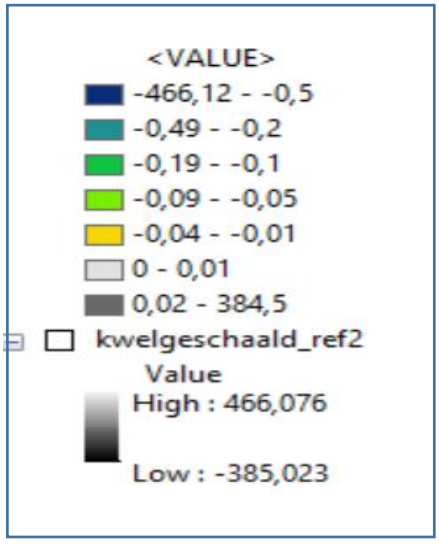
Picture 19.: ‘SeepCat.’, Deltares

For the Frisian situation there have been made already some calculations based on the groundwater quality model for the Frisian Groundwater Atlas. The maps on the following page show the achievements of 'SeepCat.' in several Climate Scenarios in this specific coastal area.
The measurement has been calculated in the mentioned atlas at page 78. In table B the Chloride content (see under VALUE) has clearly decreased (- is negative). Here, the 'SeepCat.' is used as measurement.

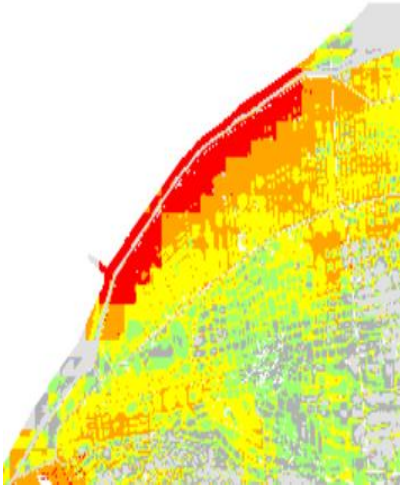
A.



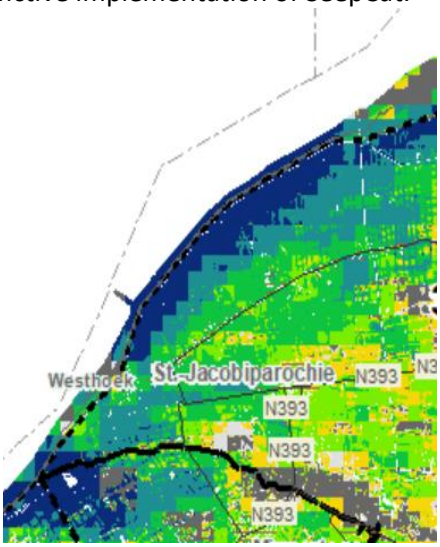
B.



Picture 20,21: Chloride value calculations after fictive implementation of SeepCat.



Picture 22.: Province, hydrology based on TNO data and GIS



Picture 23.: Province, hydrology based on TNO

In the above-mentioned atlas, the measurement is calculated for the whole Frisian coastal line over a length of 70 km and after every 100 m a vertical seepage pillar. The results of the model are promising, and salinization is decreasing compared with the autonomic situation until 2085. As a disadvantage is named in the atlas that more seepage water has extracted than is possible to dispose, approximately 13 million m^3 per year. Moreover, the maps show that in 2100 there will be more fresh water than saline. The autonomous salinization will continue to move land inward.

8.3. Fact sheet Seep Cat. through expert interview

- the thicker the pillar, the more expensive the drilling is;
- In a basic design: the distance between pillar should be 20 m., 15 m depth - diameter 200 mm of 150 mm (cheaper)
- Construction of the organising well can be made similar like the organising well of “controlled drainage” (regular drainage).
- horizontal screens are more expensive because of maintenance
- For a length of 1 km one may need 50 pillars and 10 organising wells. Costs 50x3100 euro + 10x1500 euro = 170.000 Euro
- There will flow approximately 400m^3 per day from the Seep Cat (Zeeland). This will depend on the pressure of the groundwater. This has next to tide, winter, influence on the amount. In the Frisian area this can be another number.
  With the use of pumps, the amount can increase accordingly.
- For measuring of the salt content in the surface water 2 years will be needed and a zero reference as well (see also report on ‘Perkpolder’, Deltares measuring 2017)
- The number of farmers (ha. is not mentioned) who extract water out of the freshwater lens created by ‘SeepCat’. are 3 or 4 in the Zeeland area (P.de Louw, 2019).
- If a pump will be needed depends on the level of the water in the ditches. The level in the Frisian area is 1 ½ to 2 m below sea level, which means that the level is low enough to have the seepage water flowing free into the dike ditch or through or over the dike (the latter is not yet practised).
  A pillar through the dike requires technical demands because of safety and firmness of the dike and is therefore expensive. For a technical inspection a permit is needed (A. Seinstra, ‘Wetterskip Fryslân’).

- Pumps can also be used to decline the number of drillings. A regular pump can extract 10 m^3/hour, or 240 m^3/day. This is the same as 30 un-pumped wells produce.

- An option is to use the saline water for other purposes instead of flowing. It is relatively clean water without pesticides but salt must not come into the soil. The effect must be researched first and is separating of saline and freshwater system very important learnt the Saline Futures Congress.
  The saline water will come in the end otherwise in the surface water. This is a disadvantage also for the neighbours who depend on surface water.

-Measuring of the Chloride content of the surface water requires a zero-measuring. Afterward the change in fresh and saline existence needs to be monitored (a monitoring schedule example is to be found in App. VVII. of this report)

-Seepage water can be spread by placing a divider at the end of a pillar to avoid negative effects at sea. The effect should be researched first. If the salt content is too high the Seep Cat. can be closed. This can be organised in the organising well.
-For analysing of the groundwater model is CLIWAT or Mod flow advised;
Mod flow is a groundwater model. It is needed to calculate impacts of measurements in the groundwater system. For example, the effects of extractions, or the change in level of surface water. CLIWAT was a large project which was financed by EU. Joining countries were Denmark, Germany, Switzerland, the Netherlands and Belgium. In this project the effects of Climate Change have been determined, CLIWAT (Climate and Water).

8.4. Social aspects of 'SeepCat.'

Societal costs and benefits are part of the investment in a measurement like 'SeepCat.' Besides this there are social consequences of salinization. From demographical report (Friesland scan, 2018-2019) it appears that currently a decrease in population amount is occurring in northern Friesland. This decreasing will continue in the coming decennia, with all consequences for the liveability and provision level of the region. We can think on schools, shops and public transport and libraries. In this way the area becomes unattractive for people to live and this will accelerate the population decrease. Agriculture is in this area the most important economic driver. It must be clear that every impact on agriculture has the risk that this will decline the economic situation and liveability of the region. The salinization problems need to be seen in this context. How these aspects need to be calculated is for a further specification of the CBA in follow-up research needed and because of the time period not possible in this research. The region and freshwater culture can survive but then there must be made investments for now and the future. The damage on salinization can become bigger and more expensive if nothing will be done. Though the income of a farmer will not decline because of one year of drought but there are hardly any alternatives in this region and the land is fertile and suitable for this type of crops. Employment is for the sectors behind the sector also important.

8.5. Ecological aspects of 'SeepCat.'

The essence of the 'SeepCat.' is that seepage groundwater will be caught, and the pressure in the underground is released, and in that way less seepage will become to the rootzones of plants. This caught seepage needs to be disposed but, in a way, that there is a minimum change of damage to other interests, like agriculture, nature or water system. The reduce of seepage can also be a disadvantage for neighbouring natural areas. Nature areas depend on the supply of saline water to maintain saline circumstances. Nature areas which depend on supply of saline water need to be protected. In every case there needs to be tailor made design to avoid that no other interests will be damaged. If in dike strengthening projects been captured the EHS areas in the 'Wadden' sea behind the dike should be considered. (personal announcement J. Luinstra, Province of Fryslân 2019). There can be effects on brackish nature when seepage is flowing. During the recent 'Wetsus Congress' in October 2019 the issue of disposal of saline wastewater had been discussed. A presentation of a Shell employee said that they don't dispose saline water at sea because of the impact. An EIA (Environmental Impact Assessment) will consider all environmental aspects and promotes a sustainable pattern for the physical development of land use and ownership. It is often used in planning and development projects and a requirement for certain types of projects before the can be given 'development consent' (cbabuilder.co.uk). An example of an EIA will be presented at the next page.

Example EIA

Characteristics of EIA

- The size of the project van het project;
- The cumulation of other projects, strengthening;
- Makes use of natural sources;
- The production of waste;
- Pollution and hinder;
- Risks of accidents, consideration of special substances and or technology,

Location factors to be considered:

- the current land use;
- the relatively absence, quality and recovery possibility of natural sources in the environment;
- the absorption quality of the environment.

Potential effects to be considered:

- the impact of the project (geographical, wide and involved population;
- the frontier nature of the project (i.e. is it on land of another country, institution etc., owner);
- the size and complexity of the project;
- the probability of the measurement;

The time scale, frequency and restore possibility in previous or other state

Table F
Schedule EIA (dr D. Wheatley, CBA Nothingham Trent University, 2010-2011)

8.6. Financial aspects of 'SeepCat.'

In this paragraph an overview of the costs of the several parts of the 'SeepCat.' will be given where a distinguish has been made between one-off installation costs and yearly repeating costs, like maintenance, repairing and monitoring.

8.6.1. Overview Costs and Benefits 'Seepcat.'

In this paragraph sub-question 10 will be answered.
For the overview of costs have two main variations been designed:
1. Series of seepage screen *without* pump wells;
2. A few *with* pump wells.

At the first variation there are no pumps and is the free flow of seepage in the neighbouring ditch assumed. This depends on the level of the ditch where the seepage is flowing in. It quests for a long-term insight in the levels in the ditch for the term of the investment (25 year has been used in the CBA). Has a flexible level influence on the possibility of flowing and how can this be solved? And what are the consequences for the freshwater lens if so? These questions need to be considered in the follow-up geohydrological research.

In the second variation will pumps be placed. This has as result that the volume of seepage water can increase and means less drillings and saves costs. However, the pumps need energy. To use renewable energy solar panels were used here but requires physical space. The costs of electricity have been calculated as well. To summarize, this gives 3 variations: the regular design of Zeeland without pumps, the pilot with pumps and solar panels and the pilot with pumps and electricity.

8.6.1.1. Costs

	variant 1 (without pump)	variant 2 (with pomp)
One-off costs installation costs	€ 170.000 per km (excl. design)	€ **49.600** 16 wells (3100 per piece is incl. filters); 16 pumps x 1000 = **€ 16.000** = total 10km **€ 65.600 = € 6560** per km Pump extracts 10 m^3 per hour = 240 m^3 per day. -for 600 m dike→ 6 pumps needed - for 10 km: +/- 16 pumps € 1000 per piece

		(personal announcement W. Elderhorst)		
Yearly, repeating costs	Variant 1	Variant 2		
Maintenance/incl. travel costs	**€ 10.000** Based on measuring grid A. Venema 23/5/2016	**€ 4.000** (personal announcement W. Elderhorst)		
Other costs incidental adjustments	**€ 4.000** (indication)	**€ 2.000** (indication)		
Monitoring	**€ 2.000** Indication based on measuring net A. Venema 23/5/2016	**One-off** € 600, -- per automatic pressure measuring eq., (2 per well needed) **€ 1.200** 2.500 per filter, (2 per put needed) **€ 5.000**		
Cable costs because of mice and other damage	n/a	**€ 3.000**		
One-off Permit ground	**€ 3.265** **'**Wetterskip Fryslân' (incl. research, 8 wk.)	**€ 3.265** 'Wetterskip Fryslân' (incl. research, 8 wk.)	Variant 2 with solar panels	Variant 2 with elec. net energy
Energy costs for pump: 10 m^3/hour 2 Kwh.: 1 year = 24 x 365 = 8760 hours; per year 17.500 Kwh.	n/a		3200 m^2 (200 m^2ground per well x 16) **€ 166.400** (based on € 52 per m^2)	**€ 3.850** (17.500 Kwh. x 0,22 ct.) elect. net based on net Liander

Use of solar panels at pumps	n/a		**One-off** **€ 28.000** (70 pieces (pilot) standard size, 1650 l. x 990 b. mm; 250 Kwh. apiece) **€ 400**, -- apiece. + ground in between for maintenance *) 1 average. current energy price € 0,22 ct. *)2 *)3	*)3
Use of electricity net	n/a			Liander (contract agreement unknown) 'Consumenten-bond per kWh, 22 ct. Incl. BTW (2019)
Ground costs solar panels if on ground of waterboard	n/a	n/a	Price per m^2 up to 5.000* m^2(according to council Súdwestfryslân, 2019) *Not commercial/ not build* *at large size another price possible. Here € 52 per m^2. used: **€ 166.400** 1,64 m^2 per panel is +/- € **87** x 70 pieces = € **6090**	
Total (one-off invest. per km)	173.265	68.865 688.650 ⇨	Tot.:166.400 +28.000 + 6090 = € **200.900** + costs variant 2 = 688.650	regular costs based on elec. net ((17.500 Kwh. x 0,22 ct.) **€ 3850** + costs variant 2 = 688.650
10 km pilot	**1.730.265**		**889. 550**	**692.500**

Table G: financial overview pilot

*)1 estimated 3200 m^2, space for solar panels pilot (personal announcement W. Elderhorst, 2019)
*)2 payback period 8,5 year (Milieu Centraal, 2019)
*)3 costs of energy are variable costs

Note 1.: for the ground price has one Council being used, 'Súdwest Fryslân', along the 'Wadden' coast as guidance (Sudwestfryslan,2019). The Council 'Waadhoeke', where the pilot is situated had in her program for 2019 no ground prices available ('Waadhoeke', 2019).

Note 2.: for maintenance is for equal projects 1% used in water projects (Aparicio et.al. 2019).
Note 3. The lifespan of the 'SeepCat.' is average 20 year.
Note 4. The costs of needed pre-research, geohydrological research are not included.

Optional there can be added:
- A pipeline via land to Harlingen via 'Willems Harbour', for flowing of saline seepage water directly to sea.
- A pillar through the dike can be an option but is tide and high water a reaction for 'SeepCat.' to catch more seepage water and is the flowing not possible. This will need a pump and makes some extra costs will be needed. Both options quest for more research.

8.6.1.2. Benefits

For the benefits there must be distinguished *to monetarise* but is the way in which damage must be determined not agreed yet and are models uncertain and the *not (yet) to monetarise* benefits. This would require more research, interviews and choices for the long term. Besides this there are benefits for farmers and waterboard 'Wetterskip Fryslân" but some of them are falling together like water quality.

1.Saving of costs for flushing: 600m^3 l. flushing water per second for 7 days and appr. 7 months in the recent year (2018). (personal announcement hydrologist Province).
: 60 x 60 x 24= 86.400 sec. a day = 51.840 m^3l. a day x appr. 7 months = 30,4 x 51.840 = 1.575.936 x 7 = **11.031.552 m^3 l**.
*) it is unclear if this is for the whole Province.

On top of this will come costs of extra material and employees and extra hours according to reports RWS (Ministerie van Verkeer en Waterstaat, 2019) and is not all data yet available.

A rough calculation of the surface of the pilot: 4 km land inward and 10 km coastal line gives 40 km^2 = 4000 ha.
Because there is not (yet) a market price for inlet water, farmers pay tax to waterboards and the latter has a duty the costs of the waterboard have been used here ('Wetterskip Fryslân'). An average of **€ 2,65** per ha. for water inlet and € **70** for irrigation (based on App. VI similar regions close to 'Wadden' sea) gives: **€ 72,65** per ha.
For the CBA these amounts are used for the benefits because from the one on top of this page is not clear if it is for the whole Province

The total area for the pilot gives then for flushing and irrigation: 4000 ha. x € 72,65 = **€ 290.600**

According to App. V. there are 74 farmers *) (indication). This is the answer on sub-question 9b.
*) Because of the new Law on Privacy there is no entrance towards commercial data or other and is therefore based on old data. This will require more research.

Per farm the costs for flushing are **290.600**: 74 = **€ 3920, --** per farmer a year.
These are production costs.

2. *Prevented damage*: yield amounts like presented in Excel file on pag. 76 of this chapter. This is an average which is calculated over the last 10 year based on CBS data. Other commercial tools and prices were not available during this research.
PM: (nog) niet te kwantificeren baten

3. *Water security*

4. *Clean, cleaner, sustainable water*, (less risk on increase of pesticides in situation of salinization → gives next to water quality a higher yield. Interest of waterboard (KWR operational guardiancy)
*) the costs per ha. (amount of active substance) **440 euro per ha**. (Agrimatie, 2019).

These costs can not one to one be connected to a measurement as 'SeepCat.' but has mitigation of salinization obviously an impact. The amount should be calculated and is regional data and research needed.

5. *Survival of fresh water high value crops and value of ground* + contribution toward regional and national economy.
6. *Area development/ attractiveness* for new investors and citizens. Welfare level., employment also for sectors
7. *Landscape guardiancy* if sustainable executed and nature inclusive.
8. *Mitigating Climate Change* and improving of health for humans' beings, animals and eco-system in the short and longer term.

Benefits waterboard 'Wetterskip Fryslân'
1.No/fewer flushing costs;
2.Contribution to water quality goals;
3.Innovative knowledge regarding salinization which can be exported;
4.Possibilities for sustainable circular water use, Food-Energy-Water-Nexus.

8.6.2. Costs and benefits analyse

To calculate the costs and benefits one object of the research will be explained first and then the results will be presented in 3 graphs and discussed.

Introduction

The CBA method is based on the nett profit estimation of each probable choice. The project choice is based on the difference between benefits (the amount of money of damage and has been spend on flushing and the costs of Seep cat. to prevent these costs of damage and flushing in this case). Between two regular types of CBA analyses (ex-ante = before, ex post= afterward, Boardman et.al., 1994), is the ex-ante CBA used for this research. Other factors which are described at p. 73 and in the previous paragraph are not considered yet here.

8.6.2.1. NPV

The CBA concept involves that a project can only take place if the benefits are higher than the costs. For this purpose, the benefits have been compared and calculated by using a formula in Excel: *NPV = ∑ PV (B) - ∑ PV (C)* where PV (B) is the current value benefits – PV (C) is the current value of costs. NPV is also the total internal profit.
For this research project the investment costs are calculated in 3 variations like mentioned before (p. 65). The NPV (=Net Present Value) is a calculation manner to indicate if a project is profitable or not during the economic life span (horizon). A negative value implies not possible. The NPV formula which is described underneath is the most import project investment evaluation and one of the most important tools to analyse water projects.

Formula NPV: $NPV = \sum_{t-1}^{T} \frac{NP_t}{(1+r)^t}$

NP_t= nett profit per year
$_t$ = relevant year
r = discount rate
T = project horizon

8.6.2.2. Results

Variant 1.

Rente						
1.80%		Jaar	Cash flow	Present value		
		0	-1,730,265.00	-€ 1,730,265.00	Totaal	-€ 997,458.14
		1	36,659.19	€ 36,010.99		
		2	36,659.19	€ 35,374.26	NPV	-€ 1,724,155.14
		3	36,659.19	€ 34,748.78		
		4	36,659.19	€ 34,134.36		€ -1,709,898.78
		5	36,659.19	€ 33,530.80		
		6	36,659.19	€ 32,937.92	IRR	-4.3902%
		7	36,659.19	€ 32,355.52		
		8	36,659.19	€ 31,783.42		
		9	36,659.19	€ 31,221.44		
		10	36,659.19	€ 30,669.39		
		11	36,659.19	€ 30,127.10		
		12	36,659.19	€ 29,594.40		
		13	36,659.19	€ 29,071.12		
		14	36,659.19	€ 28,557.09		
		15	36,659.19	€ 28,052.15		
		16	36,659.19	€ 27,556.14		
		17	36,659.19	€ 27,068.90		
		18	36,659.19	€ 26,590.28		
		19	36,659.19	€ 26,120.11		
		20	36,659.19	€ 25,658.27		
		21	36,659.19	€ 25,204.58		
		22	36,659.19	€ 24,758.92		
		23	36,659.19	€ 24,321.14		
		24	36,659.19	€ 23,891.10		
		25	36,659.19	€ 23,468.67		

Table C. variation without pumps

NPV: - € 1.724,155,14
IRR: - 4,3902%

Variant 2.

Rente						
1.80%	Jaar	Cash flow	Present value			
	0	-889,550.00	-€ 889,550.00		Totaal	-€ 156,743.14
	1	36,659.19	€ 36,010.99			
	2	36,659.19	€ 35,374.26		NPV	-€ 883,440.14
	3	36,659.19	€ 34,748.78			
	4	36,659.19	€ 34,134.36			€ -869,183.78
	5	36,659.19	€ 33,530.80			
	6	36,659.19	€ 32,937.92		IRR	0.2307%
	7	36,659.19	€ 32,355.52			
	8	36,659.19	€ 31,783.42			
	9	36,659.19	€ 31,221.44			
	10	36,659.19	€ 30,669.39			
	11	36,659.19	€ 30,127.10			
	12	36,659.19	€ 29,594.40			
	13	36,659.19	€ 29,071.12			
	14	36,659.19	€ 28,557.09			
	15	36,659.19	€ 28,052.15			
	16	36,659.19	€ 27,556.14			
	17	36,659.19	€ 27,068.90			
	18	36,659.19	€ 26,590.28			
	19	36,659.19	€ 26,120.11			
	20	36,659.19	€ 25,658.27			
	21	36,659.19	€ 25,204.58			
	22	36,659.19	€ 24,758.92			
	23	36,659.19	€ 24,321.14			
	24	36,659.19	€ 23,891.10			
	25	36,659.19	€ 23,468.67			

Table D: variation with pumps and solar panels

NPV: - € 869,183,78
IRR: 0,2307% = < 1.8% rente
Variant 3

Rente						
1.80%	Jaar	Cash flow	Present value			
	0	-513,385.00	-€ 513,385.00		Totaal	€ 219,421.86
	1	36,659.19	€ 36,010.99			
	2	36,659.19	€ 35,374.26		NPV	-€ 507,275.14
	3	36,659.19	€ 34,748.78			
	4	36,659.19	€ 34,134.36			€ -493,018.78
	5	36,659.19	€ 33,530.80			
	6	36,659.19	€ 32,937.92		IRR	5.0638%
	7	36,659.19	€ 32,355.52			
	8	36,659.19	€ 31,783.42			
	9	36,659.19	€ 31,221.44			
	10	36,659.19	€ 30,669.39			
	11	36,659.19	€ 30,127.10			
	12	36,659.19	€ 29,594.40			
	13	36,659.19	€ 29,071.12			
	14	36,659.19	€ 28,557.09			
	15	36,659.19	€ 28,052.15			
	16	36,659.19	€ 27,556.14			
	17	36,659.19	€ 27,068.90			
	18	36,659.19	€ 26,590.28			
	19	36,659.19	€ 26,120.11			
	20	36,659.19	€ 25,658.27			
	21	36,659.19	€ 25,204.58			
	22	36,659.19	€ 24,758.92			
	23	36,659.19	€ 24,321.14			
	24	36,659.19	€ 23,891.10			
	25	36,659.19	€ 23,468.67			

Table E: variation with pumps and electricity net.

NPV: - € 507,275,14
IRR: 5.0638% > 1.8% rente

A discount rate of 1.8% is used which is in accordance of OECD for such projects (OECD 2018). It is possible to use a so-called 'sensitivity analyses' if there is uncertainty towards the discount rate.

'If an IRR value, which is the value where the NPV is equal to 0, is higher than the social discount (the discount rate here was 1,8%), then gives this an economic justification to have the project started. (cbabuilder.co.uk*)*

Conclusion: variation 3 is the only project where IRR is higher than the social discount rate and the economic justification to start this project.
The NPV is however a monetary indicator, the IRR is a percentage

8.6.2.3. IRR

The IRR is the indicator for the investment efficiency and a measuring where 2 projects are compared. It is also be called the *break-even discount rate.* In general, it counts that the higher "the Internal Rate of Return" the more desirable it is to choose and appeals to the profit ratio which the investment receives. The project regarding the current situation versus the new one with the highest IRR is the best option. The formula is the same as NPV but is put on 0. IRR = internal rate of return (=internal efficiency)

Formula NPV: $NPV = \sum_{t-1}^{T} \frac{NB^t}{(1+IRR)^t} + NBo = 0$

NB_0= the initial investment costs
NB_t =nett cash inflow for period ^{t}
$_t$ = the time period

However, there are some restrictions to use an IRR. It can be the case that more than one project is equal to 0. This is at more than one discount percentage. Furthermore, an IRR should not be used to choose out of projects which are different in seize.

The costs of water and of ground will decide whether water projects have a change of succeeding (Aparicio et.al. 2019). This conclusion has been checked by using a fictive price for water similar as the price used in the Go-Fresh project. If this amount is added to the amount of benefits the NPV will become more positive.

Also, the adding of benefits, for example the amount of pesticides, will bring the SeepCat. measurement closer.

8.6.2.4. Scenarios

For thinking about scenarios sub-question 13 some suggestions have already been given and can influence the NPV. However, the benefits and costs need more input and variables (LEI Report 2015-012) and should be added other factors (WUR,2015). Another possibility is the scenario "do nothing". The costs of "do nothing" can be calculated also with considering more variables then could be done in this research. This comparing with "do nothing" scenario can also involve putting the invested money into a bank account. This is however not solving the situation but just a scenario.
The insight in salinization damage costs are therefore important.

Because of the complexity, many uncertainties and lack of data, the criticism on models, risk maps, no use of growing stadia and lack of coherent ordering in classes but also the lack of commercial tools for pricing and yields and finally the lack of data on costs of restoring of the water balance and damage which needs also calculation and inclusion in CBA the scenarios cannot be worked out further yet.

The scenario where a business case is made from the circular use of saline water which has been extracted needs further research as well. Depending on the volume choices the Province wants to extract this should be researched in the pilot project.

As well a scenario with a calculation where the price of irrigation water is used like in the GO-Fresh project 'Freshmaker'. This can make another picture and shows the urge to invest. As an example, has the flushing water been used of last year:

(2018): 11.031.552 m^3 l. x 55 ct. if irrigation had been calculated according to the Go-Fresh project used amount € **606.735.360** (it is not clear again if this flushing is for the whole Province). In this scenario a 'SeepCat'. investment will come closer. If the freshwater lens grows can costs be saved for flushing and this water being used for drip irrigation.

8.6.2.5. Time scales

To have an indication of the time scales the results of the Frisian Ground Water Atlas with the fictive implementation of Seep Cat. and calculated in hydrological models as shown also at page 60. Have been used. The KNMI Climate Scenarios (App. VIIII) Moderate 85 and Watbuf 85 are used here (2^e en 3^e column next page).

	Gegevens		
RINGNR	Som van schade tno ref	Som van schade GH85	Som van schade watbuf3 _85
0	7462	18955	8765
1	10183	20330	0
2	82546	170011	8489
3	163432	483784	4800
4	77	1263	32
5	3260	21057	0
(leeg)			
Eindtotaal	266960	715400	22086

Table A. (Excel, hydrology Province of Friesland)

The total damage according to this Excel file (table A) is resp. 26.6960, 715400 and 22086 (unclear is however if this is per year and in which unit) (hydrology department Province of Friesland)
The so-called 'ringnummers' correspond with areas in Friesland to know:
1.= Greidhoeke
2. = Franekeradeel
3. = het Bildt
4. = N. Friesland
5. = Lauwersmeer

These areas are all along the coastal line. In column 3, the 'Bildt', where also the pilot area is, can be seen the highest damage. This will increase in column 2 and only decreasing in column 3.

These calculations in the atlas and the implementation of the 'SeepCat.' (page. 78,79 of the atlas) and connecting with the KNMI scenarios gives also an impression of the water buffer. The total precipitation is considered. For columns 1 to 3 this is:

- Column 1: precipitation – 1%
- Column 2/GH85: precipitation surplus 0.5%
- Column 3/Watbuf3 precipitation surplus 4%.

In order to have an overview it is essential to combine the results of the CBA variation 3 with a "do nothing" scenario and the total buffer of precipitation. Depending on the price for water and the

ground (these are not known) more grip can be gained for the scenarios. In the above calculation is not clear as well if the price elasticity is calculated and the damage because of extensive waterfall which is advised in LEI report (WUR,2015).

8.6.3. Discussion results and uncertainties

Measuring in practise will give knowledge and better data to make reliable damage calculations. Besides some information is not available because of commercialised tools. Prices can fluctuate during the season. The data used in this research is from inconsistent sources and therefore not consistent. Data regarding crops is not available on a regional level. The data from the GIS file used for information on parcels is from 2007. Salinization damage and damage on drought is not yet to separate. Damage can also happen because of diseases and plagues (WUR).

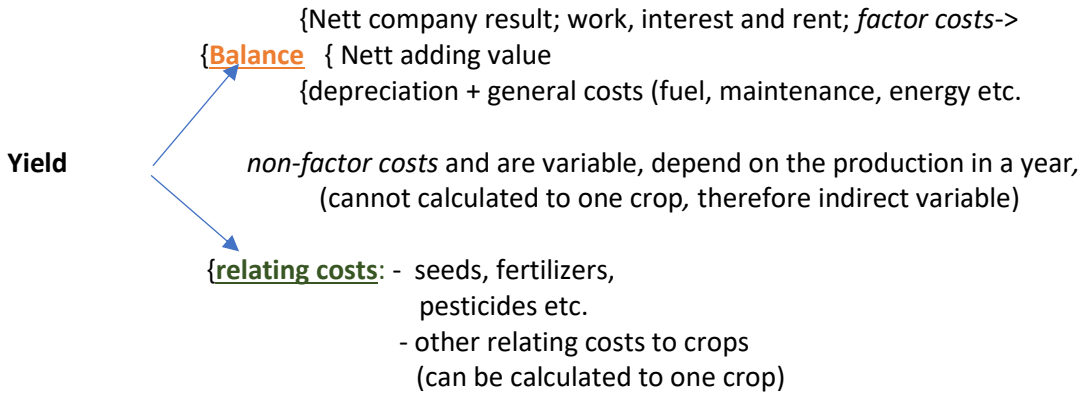
The in this research analysed data on damage percentage of the total yield per ha. based on an average of 10 years (CBS, table B p. 73) for the most important crops in this provincial area is: **504,60 ha**. This is connected to the average costs of flushing (based on 2 pilots in neighbouring area) € **72,65** per ha. ('Wetterskip Fryslân' App. IV) makes that the prevented damage costs are indicated as **€ 36.659,19** for the pilot area. For the calculation of the 3 variations this number has been used because it seemed the most secure. The uncertainties in this calculation are, however, fluctuation in price, inconsistent sources and provincial (CBS) instead of regional data. Further, these are only prevented crop damage costs which are the benefits in the case of a measurement of 'SeepCat.' and used in CBA. Soil, value of ground, micro and macro-economic factors (see page 74) are not included.

L	M	N	O	P	Q
	Gem.opbrengst over 10 jaar			2018 t.o.v.gemiddelde	
wintertar.	9,01			=	
zomertar.	7,02			<	
w. gerst	7,91			>	
z. gerst	6,51			>	
snijmais	44,08			<	
koolzaad	3,93			>	
vlas vezel	3,86			<	
zetm. aard	41,75			<	
suikerbiet	81,23			<	
zaai-uien	56,19			<	
zaai-uien	51,6			<	
na uitval					
cons. ad.	48,39			<	
op klei					
cons. ad.	44,17			<	
zand of veen					
				<	
poot ad.	56,8			>	
op klei					
poot ad.	42,15			<	
op zand of veen					

Table.B: average yield (gross x 1000 kg) of most important crops in the pilot area
Ref.: CBS
As reference for the file the following reports have been used:
Ref: 'tabel voor volle bladgroente Delta Hoofdrapport
Ref: 'CBS 10 jaren gemiddelde'
Ref: 'Leven met zout water,' Van Dam, 2019
Ref: 'Inventarisatie gewasschade op basis van bestaande gegevens' (WUR, 2016)
Ref: 'Kennis voor Klimaat, 2015 edupot.wur.nl'

For this research and in general to have an underpin for salinization percentage on drought and salinization according to RWS the report 'beleidstafel droogte' is relevant for the drought situation of last year and the salinization problem.
However, in this report a total view was used but not relevant in this research because of the agricultural scope. Moreover, the effects of the drought of 2018 had still impact during this research and needed groundwater quality and irrigation concern. It stipulates that the agricultural sector is a touched sector during drought. Hard data regarding salinization damage is not yet available. There have been listed regions which have suffered from damage on crops by RWS.
The northern clay area in the Province Friesland had damage because of the irrigation ban (Stokkers et.al, 2018). This will be of influence and it appeared that recovery takes a long time. These costs should also be calculated. These costs can be used in the benefits of the CBA and notes that the image is not yet complete.

Of importance for calculating of yields there must be made an distinguish between the *micro* and *macro* level. This is more accurate than only the physical yield itself ((WUR, 2015). This recommendation has been done for drought circumstances but has parallels for salinization.
The *micro* level is the company level where company and productions costs are calculated in the determining of yield. A global description based on figure Everdingen et.al (2014) and gives insight in how yield is complete stated which was not possible in this research because of lack of data and time available.



The company's economic balance (= yield minus variable costs) can serve as a measure for lost welfare (Brouwer and Huinink, 2002). In practise different products have a different impact on the variable production sources. The production plan in agriculture with a maximum profit depends not only on yield but also on variable costs (LEI, 2015).
A change of balance as measure gives an incomplete image of welfare change (WUR,2015).
Of importance is also the reaction of the farmer because there can be a change in company risk on the long term. The influence of weather extremes is going further than only a change in yield in a certain year and the average yield over a couple of years (Polman et al., 2012). Production risks change because of weather extremes and the larger chance on diseases and plagues. This is a fact during salinization and the fact that pesticides will not work properly because of the reaction with salt as well and has an impact.

At *macro* level it is of importance how the situation in other countries develops. Recently, the Saline Future Congress (Leeuwarden, 2019) learnt that more countries suffer from salinization and this will increase. The scope for this part in this study is however meant for EU. An advantage for the Netherlands is still that there is a rainwater surplus in winter. If fresh water supply can remain capital intensive crops can remain and is the market position for these products in the Netherlands compared to other countries with freshwater availability more optimistic.

In general, it is still assumed that damage on crops will be compensated by higher prices (HHSK, 2014). This is at short term. In the long-term agricultures will adapt to avoid risks. A combination of measurements will be needed to avoid damage and needs change of the agri-water-system.

By combining hydrological and economical models there can be made analyses but the model like Agricom does not take all-in consideration like price elasticity. (change in price if market is small). This price elasticity is also to apply when salinization damage occurs. In a more macro economical prospect, it can be concluded that the Saline Future Congress learnt that more countries in EU suffer from salinization and degradation of agricultural ground and this will increase. It will influence the price. The advantage for the Netherlands is that we have rainfall. If the freshwater system can be sustained high value crops can be grown. Underneath have been listed some considerations of indictors which are not/ or are mentioned in some models. For a description of Agricom is referred to Bakel et al. (2009).

Characteristics of some models and consideration of indicators:

	Elasticity	Export value via price	Export value via indicator	Welfare consumer
'Argricom'	no	yes	No	no
'Inkomen van de landbouw'	yes	yes	No	no
'Welvaart wereldwijd'	yes	yes	No	yes
'Welvaart in Nederland'	yes	yes	yes	yes

Table 5.2 Overzicht van de informatie over elasticiteit en export, kenmerken in de berekening van de baten (WUR, LEI 2015)

To summarize; for the calculation of damage indicators must be added like:
- variable costs;
- reaction choice of farmer (physic, other crop), change in company risks
- damage when heavy rainfall occurs
- adaptive measurements of farmer
- price effect

In many researches the tool €ureyeopener has been used. This is a commercial calculation tool for agro-hydrological calculations. This tool was not available for this research. It is recommended to have such a tool next to the measuring data of the project "Boeren meten water" and adding of above-mentioned variables. A more precise CBA will be possible to make.

Finally, the extreme weather insurance is not used in the northern part of the country last year which can have several reasons. Farmers have no insurance for this, it is too expensive, or they don't know. This is also a measure and promoted by government but doesn't solve the problem and freshwater management.

8.7. SWOT

For this research a SWOT analyse was made where in short advantages and dis-advantages are presented.

Strengths	Weaknesses	Opportunities	Threats
protection freshwater lens	disposal of seepage water in natural areas/ditches	Combining possibilities with ongoing or future dike safety-projects and saves costs	Saving of fresh water will become less important if lens is growing, pitfall
can be easy implemented in dike safety measurement (a fundament can be made f.e.) the space is not used for other functions	public money needed	Compensation measurement for gas mining damage and salinization increase	Disposed water can be harmful for natural areas in 'Wadden' sea and dike ditch
freshwater lens will grow under right circumstances	Extensive costly monitoring will be needed the first 2 years, but is also employment opportunity	World-wide attention if combined with Blue Energy, which has a lot of attention. Tourism boost.	Attraction of seepage water
Calculation in Frisian Groundwater Atlas shows that in the long-term fresh water will become more than saline.	Technical security if pipes must be made through dike	Relatively clean saline water without pesticides. Medical/other products use opportunity/circular use	
Low maintenance costs	Technical evaluation is not available yet	Jobs	
Promising results		contribution in creating a vital rural area, ambition of Province	
Creating trust and stability in area which suffers from salinization		time in transition towards sustainable agriculture	
No 'Waterbed" effect		achievement for Climate goals if combined with 'Blue Energy'	
Creates a vital soil structure which can store CO2 and fresh water			

Table H: SWOT

Chapter 9. Recommendation and conclusion

Recommendation

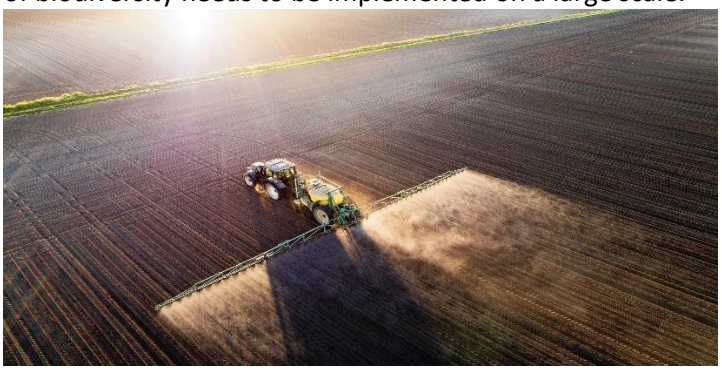
1.Data which is obtained via projects is needed on a regional level. It is important to have the data in one place. The “Knooppunt Zoet-Zout” is used for this. It is also practical and desirable to have data at the Province, a neutral place.

2.A ‘department agriculture’ must not become de-represented. Salinization in the northern provinces needs attention in The Hague. The public information site of government is saying that the problem is only in the south and western part of the Netherlands ((Deltaprogramma Zoet water, filmpje Rijksoverheid). The ‘Saline Futures Congress’, ‘Wetsus Congress’ and this research among others show that salinization needs attention as well in the northern part of the Netherlands. As a result of soil subsidence, Climate Change and therefore Sea level rise processes under the ground will continue and move further. The ‘Lake Ijssel’ sharing matter is actual and the policy to have northern Provinces independent. This cannot involve that the northern Provinces do not need facilitating in order to have a future proof and resilient food production system where fresh water is crucial.

3.Measurements like ‘SeepCat’. are suitable for dike strengthening projects. This will save costs.

4.The caught seepage water should be used for circular approaches. It is relatively clean water without pesticides.

5.Further regional research by interview among others is needed to show the situation of use of pesticides and salinization.
Furthermore, should in a pilot pesticide-producers been involved to develop nature-based alternatives. These are available but not yet used on a large scale. Also, natural pesticides with help of biodiversity needs to be implemented on a large scale.



Picture 25: NRC, farmer using pesticides in spring for fungi 2019

The use of pesticides must be prevented. Recent research, but needs more research, announced that the illness of Parkinson is related to the use of pesticides (NRC, 2019). Farmers and other groundworkers, but also the water should be protected in the first place

6. The possibility of existence of unripe clay needs attention.

7. It is recommended to use a tool as €ureyopener next to measuring of the “Boeren measure water”.

Conclusion

1.To decide if Seep Cat., a proven technology, can contribute in the solution of the problem of salinization in the Frisian north western coastal area the object of this research can be concluded based on rough data that the CBA in form of IRR shows that the technology in a variation with pumps and electricity from grid can economically be justified because the percentage of the outcome is bigger than the used discount rate in the CBA. For the other two options the IRR is smaller which implies these options are not justified.

2.Further geohydrological pre-research and choices on volume of seepage among others is needed to decide if 'SeepCat.' is the best solution for this problem in this region and suits the goals which are meant. These question and guidance can be found in Ch. 8
Additional input on CBA will also develop decision making.

3.More research is needed to find circular approaches which can be used to make 'SeepCat.' more efficient.

4.Where salinization occurs because of gas-salt mining a 'SeepCat.' can be a satisfying compensation measurement.

5. A measurement like Seep Cat will give stability in coastal areas suffering from external salinization, and suffering from more forecasted drier periods which increases the risks on damage also because of salinization and prioritising rule. In the transition to sustainable agriculture it can be hold as prerequisites and will food production and quality be safeguarded and at the same time the soil be restored and re-valued for CO_2 storage and storage of fresh water.

6.Although flushing is the common current water management policy, in times of drought when water quality can become a serious issue flushing is transporting the problem to another place instead of solving water quality itself (HHSK, 2014).

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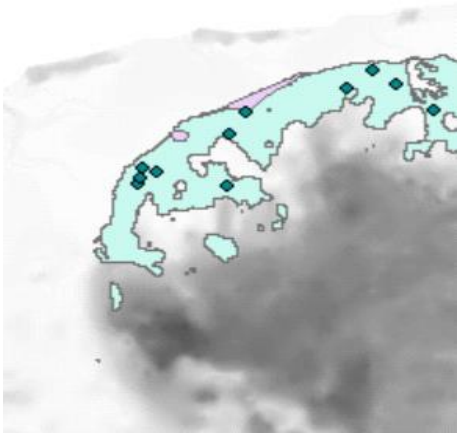
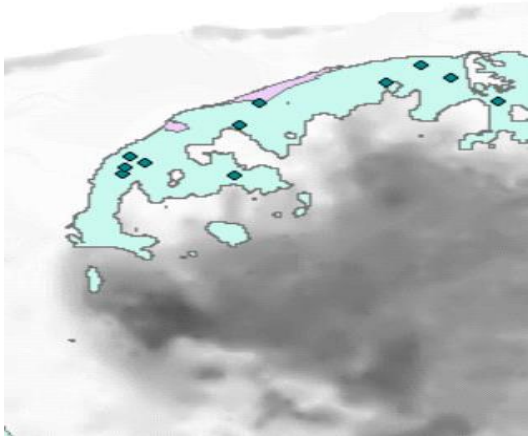
App. I.: Measuring Chloride content in some parts of the northern western region of Friesland

Place	1e measure Cl.	Mg/l	2e measure EC-micro Siemens	EC-micro/milliS	Temperature Celsius	(Measuring on 18 June 2019)
Zwarte Haan		725		1053	22,4	
		1955		2,84	21,7	
Fiskefeat		858		1239		
Ropta		17,64		2,54	23,3	
Vishevel		13,81		19,82		
Ropta slootje		2,24		1563	23	
Wierum punt 1.		1000		1468	18,9	(measuring on 27 June 2019)
point 2.		1032		1495		
point 3.		1200		1730		
point 4. 'droge slootje'		824		1200	16	
at dike point 1.		3140		4,56	20	(influence dike)
at dike point 2.		8280		11,3		
Bollingwier point1.		1250		1815		
point 2.		650		994		
point 3.		1998		1343		
Hantum (situated lower)						
point 1.		2560		3,74		
point 2.		2700		3,91	17,8	

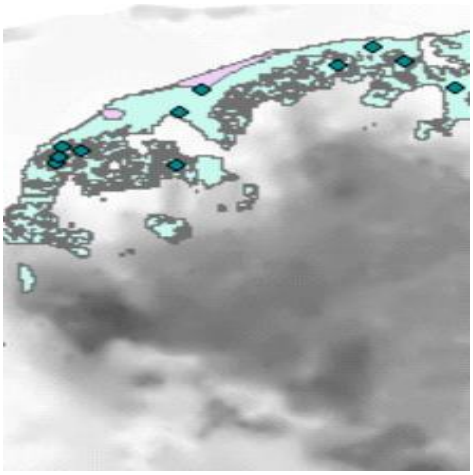
App.II: Data: underpin map Acacia Water (Spaarwater, rapport 2019)



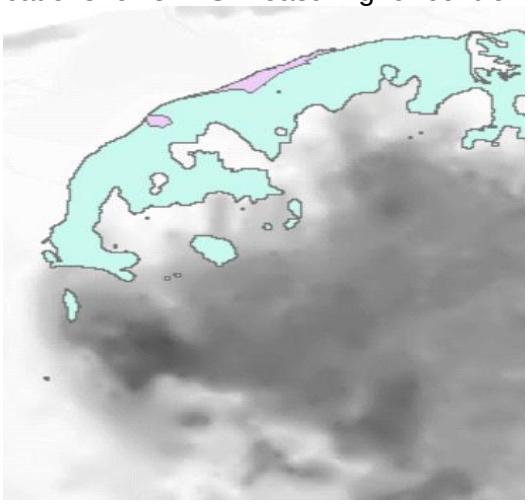
Brackish-saline



locations for CVES-measuring for control

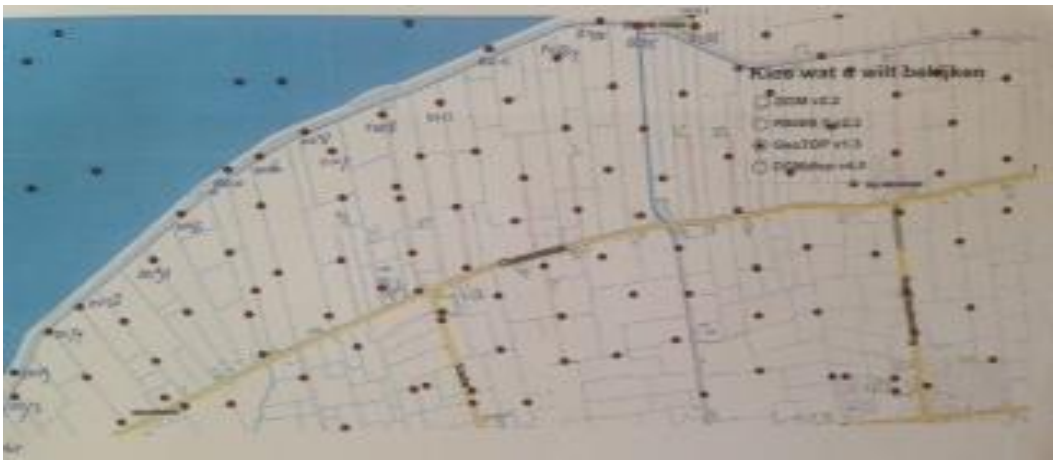


Possible unripe clay



uncertain fresh-salt front

App.III: measuring places + coordinates of the pilot area of the research



	Westhoek	Zwarte Haan		
Coordinates	**Drilling nr.**	**Map nr.**	**Depth** well (m)	**Sand layer**
166370/587800	B05E0065	05E	5	0,3 - 5
166500/588130	B05E0073	05E	4	0 - 4
166760/588720	B05E0009	05E	17.5	5.6 – 11.6 + thin layers
166980/588940	B05E0074	05E	4	0.4 - 4
167500/589360	B05E0038	05E	97.25	10.25-15.25/16.25-24.25
167700/589770	B05E0091	05E	5	3-5
168040/590160	B05E0092	05E	4,8	2.6 – 4.8
168260/590280	B05E0010	05E	17.5	5.7 – 8.8 and 9.6 – 15.5
168580/590500	B05E0106	05E	4.8	0 – 4.8
168760/590330	B05E0037	05E	17.5	5.7-8.8 and9.6 – 15.5
169120/590650	B05E0107	05E	4.8	0 -4.8
169520/590760	B05E0108	05E	59	2.4-7.5 and 9.9-13 and 15.2 – 23.4
169520/590760 (RD)	B05E0111	05E	5	1.4 - 5
169873/591228 (RD)	B05E0011	05E	17.9	7.3 - 14
170900/541420 (RD)	B05F0285	05F		

171300/591410	B05F0288	05F	5	0.2 - 5
170641/541456	B05F0410	05F	8.5	3.0 – 7.6
	B05F0285	05F	3.8	3 – 3.8
171270/591510	B05F0061	05F	91.25	3.25-5.25 and 14.5-21.25
	Oosterbierum	Koehool	Westhoek	
158220/579180	B05D0292	05D	5	More layers
158530/580220	B05D0116	05D	5	5,8 – 13,7 and 22,6 - 51
158920/580950	B05G0301	05G	5	2,3 – 4,6
160030/582140	B05G0079	05G	31	11-19
160640/582240	B05G0679	05G	5	1,4 – 3,5
161400/583650	B05G0098	05G	59	3.8 – 22,6
161925/583870	B05G0072	05G	33	14 - 19
163980/582280	B05G0097	05G	94,25	4,25 – 19,25
164068/585360	B05G0847	05G	7,3	3,7 – 7,3
164424/585628	B05G0850	05G	7,5	4,8 – 7,2
165700/586710	B05G0096	05G	55	8,1 – 22,5

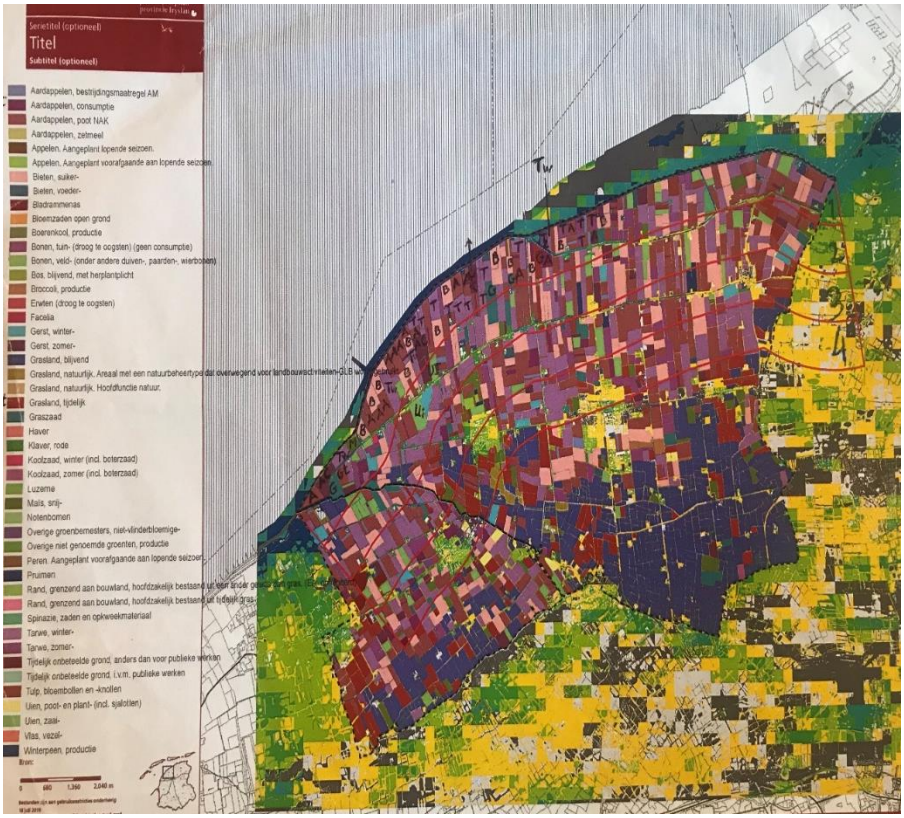
App. IV: Table Waterboard “Wetterskip Fryslân”, costs of flushing

Tabel 5.3.1 Berekening kosten doorspoelen in de pilotgebieden

Kostenberekening pilotgebieden	**Ropta** 4514 ha, waarvan ca 160 ha beregend		**Kimswerd** 2830 ha waarvan ca 100 ha beregend	
	Investerings kosten	Jaarlijkse exploitatie kosten	Investerings kosten	Jaarlijkse exploitatie kosten
Kunstwerken	€ 23.800	€ 1.465	€ 22.700	€ 1.395
* Duikers	€ *13.800*	€ *850*	€ *2.700*	€ *165*
* Stuwen	€ *10.000*	€ *615*	€ *20.000*	€ *1.230*
* Inlaten	€ -	€ -	€ -	
Gemalen	€ -	€ -	€ 20.000	€ 1.230
Uren rayonbeheerder		€ 2.850		€ 1.935
Zomeronderhoud				
Energie gemalen		€ 9.100		€ 1.970
Totaal	€ 23.800	**€ 13.415**	€ 42.700	€ **6.530**
per ha		€ 3,00		€ 2,30
per ha beregend (schatting)		€ ***84,00***		€ ***65,00***

Source: Wetterskip Fryslân (J. Jansen, 2019)

App: V: Parcels with the agricultural use in the pilot area

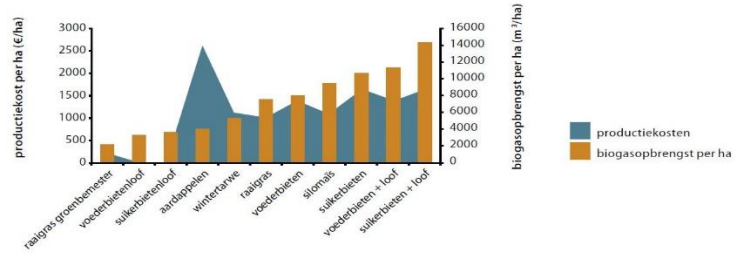


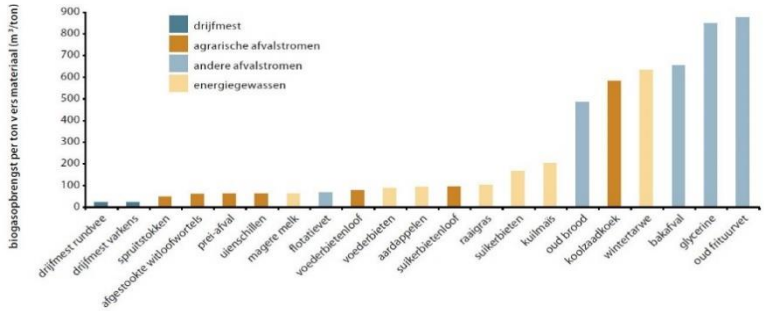
Map, Province of Friesland (GIS) distances with red line 1 – 4 km boxes from Coast (note: the crops can change!)

App. VI
Biogas potential salt/moderate salt tolerant crops

Product	Main product	Additio-nal product	Gross monetary yield	Contributed costs	Balance own mechanisation	Costs contract work	Balance contract work
Rape seed	1.456	170	1.626	737	889	132	757
Soya	976	170	1.146	506	640	314	326
Hemp oil	700	395	1.095	342	753	465	288
Flax oil	1.190	245	1.435	469	966	465	501

Balance oil containing crops (in EUR/ha). The balance for oil containing crops are positive. Rape oil has the highest balance (€757, -/ha). Flax and hemp can achieve probably better if the fibre is valued (WUR, 2008).

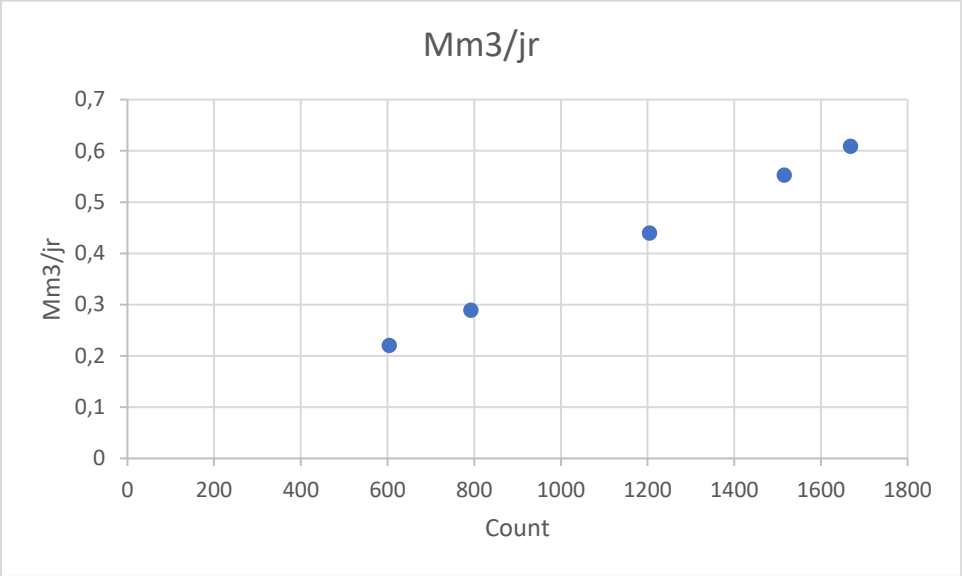




Graph, ‘de groene rekenkamer’, 2015

These graphs give the potential of biomass for crops which are cultivated in the Wadden region

App: VII. Salinization and the use of flushing water, a linear relation

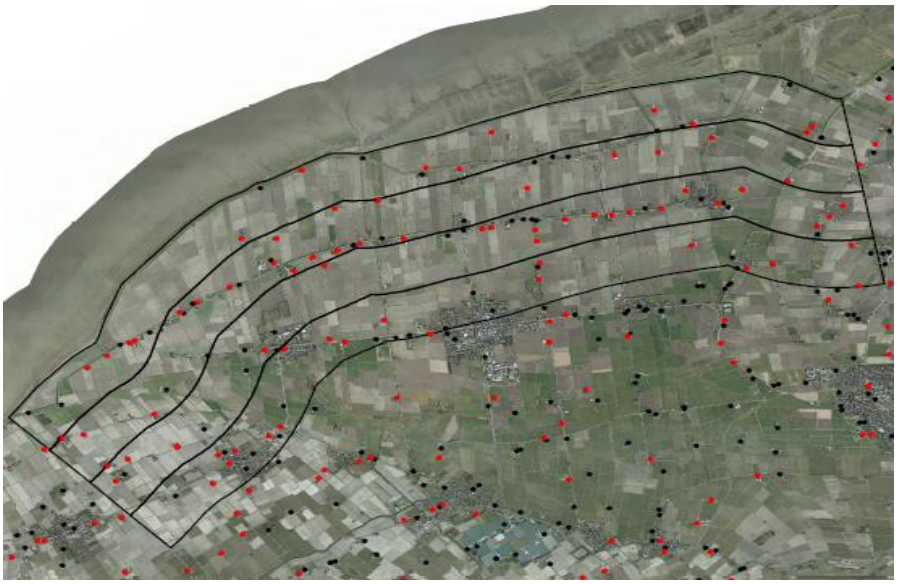


Data: (from Excel file hydrology department of Province of Friesland)

Name	**Count**
? (unknown)	604
Ropta	792
Zwarte harne	1668 *
Ferwerderadiel	1204 *
Dongeradeel	1515 *

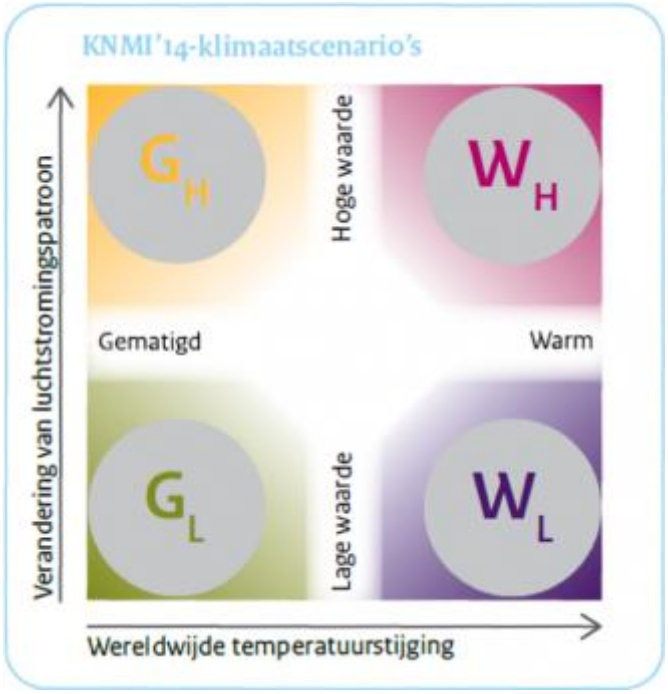
*) for the making of graph the comma has been left out

App. VIII Map GIAB (registration of agricultural enterprises) from 2014, Province of Friesland
Take care of privacy!



Map, GIAB, Province of Friesland, amount of agricultural entreprises in the pilot area per 1,2,3,4, km zone

App: VIIII KNMI Climate Scenarios



App: VV

Report visit Holwerd d.d.: July 2019

The agricultural organisation of farmers in Holwerd who are involved in the project 'Holwerd aan zee' (see: more MIRT-research, 2016) and the threat of saline water which can be a result, have organised an information evening in the context of the 'Boeren meten Water' project at the farm of the fam. Miedema. Prof. M. de Vries of Deltares, explains forecasts on Climate Change and mitigation and adaptation. The "Region Deal, "Fjildlab" (= Frisian for field lab) and is in the end opportunity for questioning. The "measuring is knowing" principle is of main importance to find proper solutions and ways to deal with salinization and is taken serious through these farmers. They acknowledge the importance of knowledge and a transition of agricultural sector towards a sustainable one. Knowledge on impact of salt in clay is also needed. It damages its structure because of Calcium. This structure is of vital importance for agriculture. However, there is confusion and insecurity among some farmers if their parcels are in the risk area because maps of the project 'Spaarwater' from Acacia give this picture. Despite the map the expert's judgment of J. Veldstra from Acacia gave after the measuring in the project 'Boeren meten Water' a more relativizing view. It is also important where measuring takes place and that the equipment is placed in the right way. In general, it can be said that salinization is under control but there will be measurements and adaptations needed. Ecosystem and sustainable thinking and practise like in "Fjildlab" is a good example and should be upscaled, invention of good monetary yield models, landscape guardiancy and collaboration remain important. These farmers are on their way to a sustainable future but the market decides still that a carrot should be straight says Mr. Miedema. There should also be a change. Besides that, salinization has the effect that pesticides don't work properly and this will give the risk that more of these pesticides will be needed. This danger is also noticed at the Platform Ijsselmeer congress last March. The flower bulb enterprise presentation mentioned this risk as a risk after the drought of 2018 and higher Chloride content, which doesn't say that all farmers will respond in this way. Prof. de Vries, ecologist, explains that biodiversity creates a natural protection against diseases with e.g. bees, ichneumon-flies and bumblebees. In this area is already made extra space for flowers and insects. It needs research to know which amount will be needed. Salinization, biodiversity and pesticides versus water quality but also products/markets and consumer behaviours and choice have a connected relation and influence. Education on agricultural universities of applied science and vocational schools on salinization is of great importance according to Prof. de Vries. He is also lecturer at the Van Hall institute in Leeuwarden, the University of Applied Science in this Province for among others agricultural studies.

App. VVI

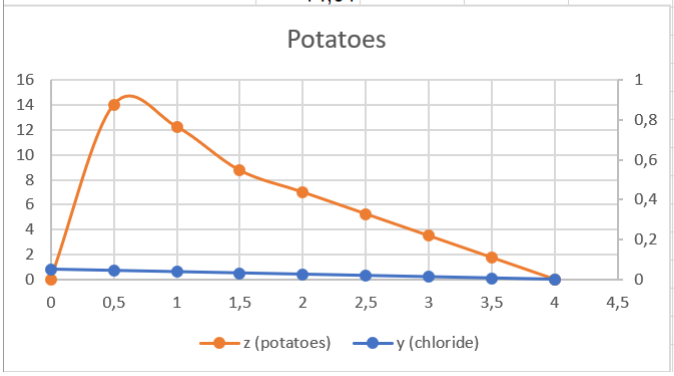
Rough calculation percentages salinization damage of some most important crops in the pilot area

Verticale coordinate1.: left is distance to coast

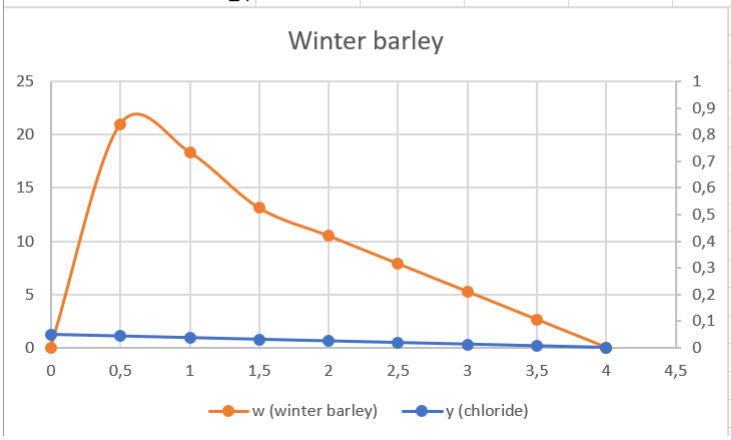
2.: right is price

Horizontale coordinate: Chloride content in Mg./L

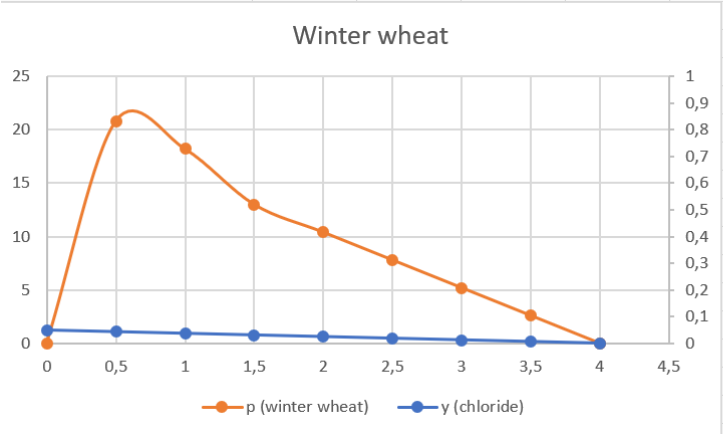
z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
z (potatoes)	0	1,75125	3,5025	5,25375	7,005	8,75625	12,25875	14,01	0
	14,01								



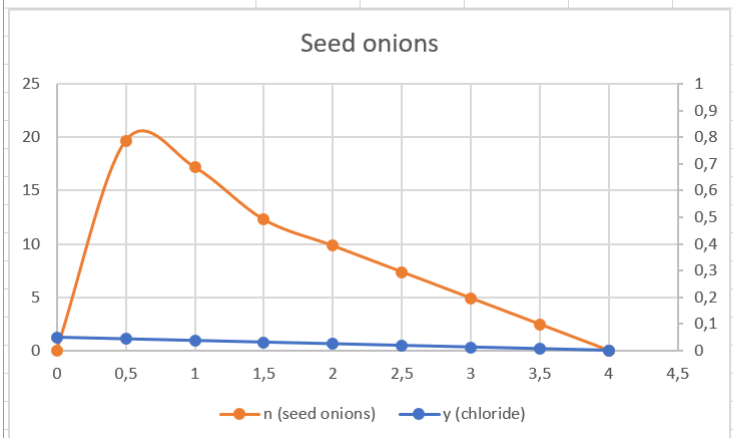
z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
w (winter barley)	0	2,625	5,25	7,875	10,5	13,125	18,375	21	0
21									



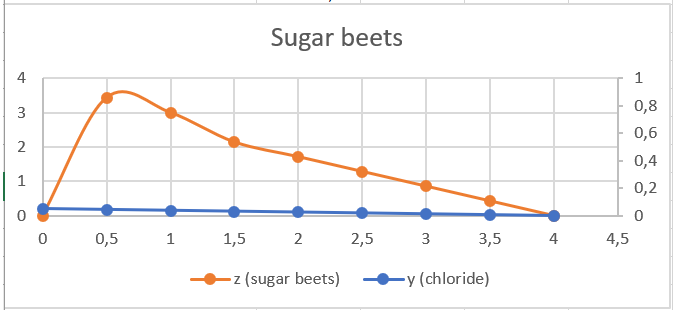
z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
p (winter wheat)	0	2,6	5,2	7,8	10,4	13	18,2	20,8	0
	20,8								



z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
n (seed onions)	0	2,4575	4,915	7,3725	9,83	12,2875	17,2025	19,66	0
19,66									



z (percentage yield)	0%	12,50%	25%	37,50%	50%	62,50%	88%	100,00%	0%
x (distance)	4	3,5	3	2,5	2	1,5	1	0,5	0
y (chloride)	0	0,00625	0,0125	0,01875	0,025	0,03125	0,0375	0,04375	0,05
z (sugar beets)	0	0,4275	0,855	1,2825	1,71	2,1375	2,9925	3,42	0
	3,42								



App. VVII

Monitoring program SeepCat. Zeeland (Deltares, 2014)

Monitoring program SeepCat. based on monitoring 'Perkpolder Zeeland' (P.de Louw, 2014)
**(details are not available because of author's rights) for more information: 'monitoring protocol kwelvoorziening Perkpolder' (https:www.zeeweringenwiki.nl/images/b/b2/De Louw Monitoring)*

I.Measuring and rise height 1wvp					
code					

type of measur-ing	filter depth m-mv	equipped with automa-tic pressure measurer	telemetric measure place	is part of follow-up monitoring	frequency of hand measuring begin- phase and pre-organising phase

frequency reading 'dataloggers' begin phase and reading phase	frequency hand measuring stable phase	frequency reading 'dataloggers' stable phase

II. Measuring change of freshwater lens					
code	type of measuring	equipped with an automatic pressure measurer	telemetric measure place	is part of follow-up monitoring	frequency hand measuring and pre-phase

frequency reading 'dataloggers' begin-phase and reading phase	frequency hand measuring stable-phase	frequency reading 'dataloggers' stable -phase

III. Measuring flowing of seepage (flow rate and salt content)					
code	type of measuring	equipped with automatic pressure measurer	telemetric measure place	is part of follow-up monitoring	

frequency hand measuring begins phase and pre-organising phase	frequency reading 'dataloggers' beginning phase and pre-organising phase	frequency hand measuring stable phase	frequency reading dataloggers stable phase