The socio-economic and ecological potential of saline agriculture on islands

an exploratory study

Jeffrey Bergkamp
Astrid Berndsen
Vicky Meulenberg
Krijn Prins

Commissioned by the Waddenacademie through Prof. Dr. Ir. P. Vellinga and part of the SalFar project.

Wageningen, 6 June 2018

Contact information commissioner
Prof. Dr. Ir. P. Vellinga
Huis voor de Wadden
Ruiterskwartier 121a
NL-8911 BS Leeuwarden
Tel: +31 (0) 58 233 9030
E-mail: pier.vellinga@waddenacademie.nl

6th June, 2018

Contact information project leader
Jeffrey Bergkamp
Droevendaalsesteeg 2
NL-6708 PB Wageningen
Tel: +31 6 57213002
E-mail: jeffrey.bergkamp@hotmail.com

This research is commissioned by the Waddenacademie, Leeuwarden, as part of the EU Interreg project "SalFar". The report is produced by students of Wageningen University as part of their MSc-programme. It is not an official publication of Wageningen University or Wageningen UR and the content herein does not represent any formal position or representation by Wageningen University.

About the authors

Jeffrey Bergkamp
Student Climate Studies, Wageningen University – Climate, Society and Economy

Astrid Berndsen
Student Climate Studies, Wageningen University – Water Management and Ecology

Krijn Prins
Student Earth and Environment, Wageningen University – Modelling and Hydrology

Vicky Meulenberg
Student Earth and Environment, Wageningen University – Meteorology and Climate Physics

Picture front page: Terschelling (Own material, 2018)

waddenacademie
Interreg North Sea Region
European Regional Development Fund
WAGENINGEN UNIVERSITY & RESEARCH

Foreword

This research is conducted for the course 'Design of Climate Mitigation and Adaptation Strategies' given by the Wageningen University and is commissioned by the Waddenacademie. The study is subsidized by the Interreg project SalFar: "Saline Farming – innovative agriculture to protect the environment and stimulate economic growth", developed by the Waddenacademie.

This study would not have been established without the help of our commissioner Pier Vellinga. Therefore, we would want to thank him in particular for his support, input, and ideas. Furthermore, our supervisor Bert van Hove helped notably with his experience regulating the organization and practicalities of the report. Lastly, for this study, we have interviewed numerous experts, farmers, public operators, entrepreneurs and other involved parties. They gave us valuable knowledge, which was indispensable for the establishment of this study.

Glossary

Saline agriculture
In this report, 'saline agriculture' is defined as the cultivation of both halophytes and traditional freshwater crops (such as potatoes and carrots) under more saline soil and water conditions. Both types of crops are considered to be of equal importance and the potential of both types is investigated in this report. Some examples of halophytes are Norfolk Samphire, Sea lavender, and Ice plant.

Salinization
Since 'salinization' is a very broad term, the importance of giving it a proper definition should not be underestimated. Hereby, we follow the definition adopted by Velstra & Voorde (2009). According to these authors, salinization is defined as the following: *'when the water (also within a soil) contains a concentration of salt/chloride which is too high for an optimal (agricultural) use'.*

Moreover, Velstra & Voorde (2009) argue that this definition consists of three aspects. There is salinization when:

- An increase in the concentration of salt/chloride is appearing.
- The water user thinks that the water is too saline.
- The water manager thinks that the water is too saline.

Rainwater harvesting
Rainwater harvesting is the accumulation of rainwater and is a climate adaptation strategy of all times (Hofman & Paalman, 2014). This strategy is gaining worldwide interest, not only to store water in dry periods but also as a measure to cope with extreme rainfall. In Crete, for instance, rainwater harvesting is being used by local farmers for crop protection (Panagea, 24 April 2018, Appendix 18).

Executive summary

Background and aim

Climate change threatens freshwater resources all over the world due to rising sea-level and longer dry periods. As a consequence, salinization is becoming a serious problem in the coastal areas of the world. Both the exponential population growth and the decrease in freshwater availability pose some real challenges to the global food production. Agricultural food production has to increase by about 70% to meet growing demands before the year 2050. Therefore, it is crucial to investigate new opportunities such as saline agriculture. Two types of crops can be distinguished that are interesting for saline agriculture, which is on the one hand the traditional cultivars being made more salt-tolerant and on the other hand the naturally salt tolerant halophytes. Investigating new opportunities is especially interesting especially on small islands, since islands are perfect places to create and establish innovative ideas. Therefore, the aim of this research project is to explore the potential of saline agriculture for small islands. The focus will lie especially on the following aspects: improving the use of resources and valuing its ecosystem services, creating a more self-sufficient food production, stimulating the tourism industry by promoting saline agricultural initiatives, and strengthening the islands' identity. These aspects will especially be studied for two Dutch islands, which are Terschelling and Texel, and two foreign islands, which are the Seychelles and Malta.

Results

According to interviews with several stakeholders and literature research currently hardly any saline agricultural initiatives exist. On Terschelling, the short-term opportunities for saline agriculture lie within the tourist sector. Small agricultural initiatives such as 'self-picking gardens' are interesting for the tourism branch and regional products can strengthen the identity on a small island. On Texel, the agricultural sector is quite large, but there is currently no urgency in making the transition towards saline agriculture. However, Salt Farm Texel is an important research institute for saline agriculture and its knowledge is used all over the world. On Seychelles, saline agriculture could enhance the tourism and employment, but the initiatives should be further developed to increase self-sufficiency in the long term. Lastly, for Malta, it turned out that saline agriculture could generate new initiatives that would make the agricultural sector more interesting for the new generation. Furthermore, because the tourist industry is partly causing the salinity issues on Malta, saline initiatives for tourists would make the situation more balanced again.

Conclusions and recommendations

The results suggest saline agriculture has above all potential when there is no other possibility for conventional agriculture. In the short term, saline agriculture could enhance identity, tourism and employment. In the long term, opportunities like saline agriculture could secure or increase the self-sufficiency of countries facing salinization. Currently, in the Netherlands, there is no need to transition from conventional agriculture towards saline agriculture. On many islands located outside the Netherlands, farmers first try other techniques such as rainwater harvesting. However, in the far future when the salinization problem will increase, saline agriculture is definitely interesting and should already be further developed at this moment. On islands where the tourist industry is important, small saline agricultural initiatives such as self-picking gardens are interesting in the short term. Furthermore, on small islands, a special regional product, such as seaweed cheese, can strengthen the identity of an island and improve the use of local resources. On top of that, if it is allowed to irrigate on the island, making conventional crops slightly more salt tolerant is interesting, because irrigating with brackish water becomes a possibility. In the long term, irrigation with brackish water can enhance self-sufficiency of an island. Lastly, Salt Farm Texel showed that islands can be perfect experimental gardens in which knowledge is gained and exported. To conclude, it is not expected that saline

agriculture will replace the conventional agriculture on islands at this moment. However, it is definitely an interesting niche that should be developed further already.

Samenvatting

Achtergrond en doel

Zoetwaterreservoirs worden over de hele wereld bedreigd door de gevolgen van klimaatverandering. Een stijgende zeespiegel en langer aanhoudende droge periodes zorgen voor een serieus probleem van verzilting in kustgebieden. Zowel een exponentiële bevolkingsgroei als een daling in zoetwaterbeschikbaarheid creëren een grote uitdaging voor de wereldwijde voedselproductie. Om iedereen te kunnen voeden zal de voedselproductie in 2050 ten opzichte van de huidige productie met 70% moeten stijgen. Het is van cruciaal belang dat nieuwe kansen om verzilting tegen te gaan benut worden. Een van die kansen is zilte landbouw. Zilte landbouw kan op twee manieren worden bedreven; het zouttoleranter maken van conventionele gewassen, of gebruik maken van halofyten (die van nature zouttolerant zijn). Door de afgelegen ligging zijn kleine eilanden een ideale testlocatie voor innovatieve ideeën. Het doel van dit onderzoek is dan ook: het vaststellen van de potentie van zilte landbouw op kleine eilanden. De focus van dit project ligt op de volgende vier aspecten: het verbeteren van het gebruik van grondstoffen en het op waarde schatten van ecosystemen, het creëren van een zelfvoorzienende voedselproductie, het stimuleren van toerisme door middel van promotie van zilte agrarische producten en als laatste, het versterken van de identiteit van het eiland. Na een overzicht van bestaande zilte initiatieven over de wereld worden er vier eilanden uitgelicht. Dit betreft twee Nederlandse eilanden: Terschelling en Texel; en twee buitenlandse eilanden: de Seychellen en Malta.

Resultaten

Na literatuuronderzoek en interviews met verschillende partijen is gebleken dat er momenteel weinig zilte landbouw initiatieven zijn. Enkele eilanden laten zien dat zilte landbouw toch wel degelijk kansen biedt. Op Terschelling zijn er op de korte termijn kansen in de toeristische sector. Zilte boeren kunnen bijvoorbeeld rondleidingen organiseren en pluktuinen, waarin halofyten voorkomen, openstellen voor toeristen. Op Texel is de landbouwsector groter, maar bestaat er nog geen noodzaak voor een transitie naar zilte landbouw. Toch is het Zilt Proefbedrijf Texel een belangrijk onderzoekscentrum voor zilte landbouw en de kennis die daar is opgedaan wordt over de hele wereld gebruikt. Op de Seychellen kan zilte landbouw de werkgelegenheid én de toeristische sector versterken. De projecten moeten echter wel verder ontwikkeld worden om op de lange termijn zelfvoorzienendheid te vergroten. Ten slotte is op Malta gebleken dat zilte landbouw de landbouwsector aantrekkelijker kan maken voor de nieuwe generatie. De toeristische sector zorgt gedeeltelijk voor het verzilten van Malta, maar de combinatie van zilte landbouw en toerisme kan de balans hierin herstellen.

Conclusies en aanbevelingen

Uit de resultaten valt te concluderen dat de potentie voor zilte landbouw het grootst is als er weinig tot geen mogelijkheden meer zijn voor conventionele landbouw. Op de korte termijn kan zilte landbouw de identiteit en de werkgelegenheid vergroten en de toeristische sector versterken. Op de lange termijn biedt zilte landbouw kansen om de zelfvoorzienendheid van eilanden te verhogen. Op dit moment is er geen noodzaak in Nederland om grootschalig over te stappen op zilte landbouw. Op eilanden buiten Nederland gebruiken betrokken partijen eerst andere oplossingen tegen verzilting, zoals het opvangen van regenwater. In de toekomst echter zal het probleem van verzilting toenemen en daarmee de kansen voor zilte landbouw ook. Hierdoor is het handig om nu al onderzoek te doen naar deze sector. Op eilanden waar de toeristische sector belangrijk is zijn initiatieven als pluktuinen interessant. Daarnaast kan een lokaal product de identiteit van een eiland versterken en tegelijkertijd het gebruik van lokale grondstoffen stimuleren. Als irrigeren toegestaan is op een eiland wordt het interessanter om zouttolerantere conventionele gewassen te gebruiken om irrigeren met brak water mogelijk te maken en zo de droogteschade te beperken. Het Zilt Proefbedrijf heeft laten zien dat eilanden een perfecte speeltuin kunnen zijn, waar nieuwe technologieën getest kunnen worden en

waarbij kennis geëxporteerd kan worden naar het buitenland. De conclusie valt te trekken dat zilte landbouw op dit moment de conventionele landbouw niet volledig gaat vervangen, maar dat er zeker kansen liggen in een nichemarkt waarbij de mogelijkheden verder ontwikkeld moeten worden.

Table of Contents

1. Introduction

On behalf of the course 'Design of Climate Mitigation and Adaptation Strategies', given by the Wageningen University and Research, a consultancy project is conducted by us as four MSc-students. This project is commissioned by the Waddenacademie, with the aim to explore the potential of saline agriculture for islands. In this way, the ecological and economic potential of food production on these islands is being investigated. This project focuses on four aspects of the islands: economy, ecology, identity, and self-sufficiency. On the basis of these four aspects, an answer should be given to the following research question: *How can island-based food production under saline soil and water conditions contribute to an island's ecology, economy, and identity?*

1.1 Problem definition

Climate change threatens freshwater resources on islands due to sea-level rise worldwide (Nurse et al., 2014). First, sea-level rise causes more saltwater intrusion into the coastal areas of the world (Nicholls & Cazenave, 2010). This does not affect surface waters directly, but it affects the salinity level of the groundwater that is pumped up, see Figure 1 (OzCoasts, 2018). Second, longer dry periods mainly in summer cause a decrease in the depth of the groundwater lens (KNMI, 2015). As a result, salinization is becoming a bigger problem in the coastal areas of the world. These negative consequences of climate change have implications for our food production (Waddenacademie, 2015). Especially on small and vulnerable islands, together with growing demands, the freshwater availability has been threatened by salinization (Tompkins et al., 2005). Barnett (2011) shows in his research that for people in the islands of the South Pacific, the risks climate change poses to food security constitutes a 'dangerous' change in climate. It is, therefore, crucial to see this salinization rather as a change and not as a problem and to investigate new opportunities such as saline agriculture, which could secure or increase the self-sufficiency of small islands facing salinization. Because of their size and remoteness especially islands are perfect as experimental gardens for innovative ideas. Furthermore, a breakthrough was achieved by Salt Farm Texel in the production of crops on saline agricultural land, stimulating global food security (Rijksoverheid, 2017).

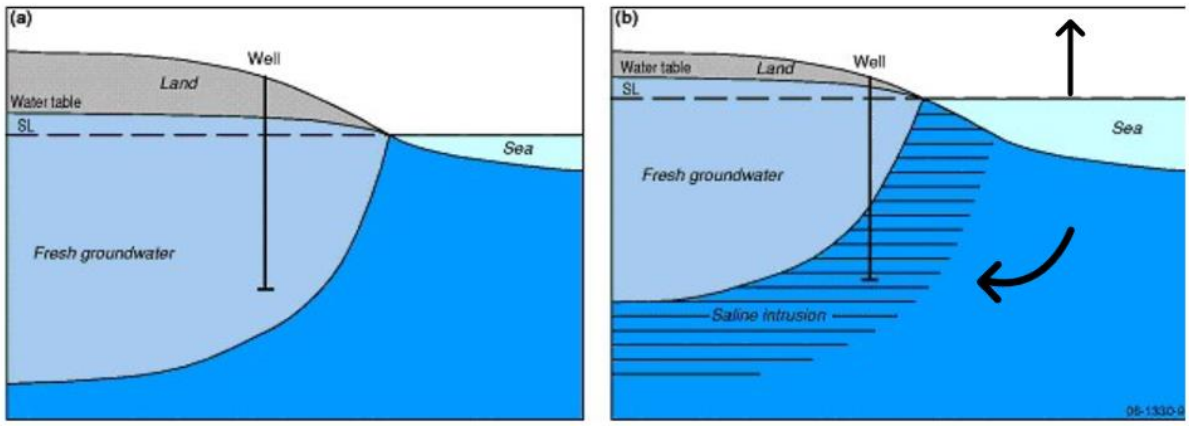

Figure 1: Extra Saline intrusion caused by sea level rise (Modified from: OzCoasts Australian Government, 2018)

1.2 Background information

In the Netherlands, in particular, it is expected that around 125.000 hectares of land will be subject to salinization by the year 2030, due to sea-level rise, drier summers and land subsidence (de Kempenaer et al., 2007; Rijkoverheid, 2017). According to NASA (2017), in the last 25 years, sea level has risen by about 3 millimetres a year. On top of that, it is projected that for the coming 15 years this rate of change will even increase to 5-10 millimetres a year (Church et al., 2013).

Both the exponential population growth and the decrease in freshwater availability pose some real challenges to the global food production. Agricultural food production has to increase by about 70%

to meet growing demands before the year 2050 (Salt Farm Texel, 2017), since it is projected that the world population will reach 9.8 billion by that time (UN, 2017).

Salt Farm Texel is a research centre experimenting with the relation between salinity levels and both the growth and quality of a diverse set of crops and *halophytes* (plants which grow in water of high salinity). By identifying salt tolerant crops, it is possible to cultivate food in salt-affected areas, which were previously assumed to be unproductive. Salt Farm Texel is located in the Netherlands, on the Wadden Sea island of Texel. The open-air laboratory of the research centre is regarded as one of the most important facilities for this project. Salt Farm Texel is not only implementing its results in the Netherlands but also in e.g. France and Pakistan (Salt Farm Texel, 2017).

Recently, a salt-tolerant potato was discovered by the company which thrives under saline soil conditions and can be irrigated with a mix of fresh and salt water (Salt Farm Texel, n.d.). Since 2014, the potato is being tested in Pakistan. Scaling up access to this salt tolerant potato will create new livelihood opportunities, together with a better use of salinized lands and waters, and a reduced pressure on freshwater resources (Salt Farm Texel, n.d.).

Not only Dutch islands cope with salinization problems; in chapter 4 'Exploration around the world', a number of examples regarding foreign islands are given. On islands such as Kiribati and the Maldives, sea-level rise has become a threat to the island's existence, causing more and more seawater intrusion. On islands like Crete and Malta, located in the Mediterranean, freshwater resources are scarce and will even become scarcer due to climate change.

1.3 Report relevance

The relevance of this report is to show involved parties the possibilities and the potential of saline agriculture on islands. The results of this project should trigger the shift towards more self-sufficient islands in which the economy will profit from the saline agriculture. Local farmers will be the first who will be affected by the increased salinity and this report can show them the possibilities of agriculture under saline soil conditions, instead of seeing this salinization as a limitation. On top of that, this report could show the tourism branch the potential of saline agricultural related activities and culinary products. Last but not least, municipalities and local water boards could be inspired by the project results to support local initiators who want to transition from producing or using conventional crops towards saline products.

1.4 Project aim

As commissioned by the Waddenacademie, this project is meant to explore the potential for saline agriculture on small islands, such as the Wadden Sea islands in the Netherlands and several foreign islands across the world like Kiribati, Hawaii, and Bahrain. This project shows the impact of the problems of salinization and illustrates the chances for saline agriculture as a solution for these problems, because it is important to see the possibilities of saline soils and not the limitations. Saline products coming from saline agriculture could consist of both halophytes and traditional cultivars made more salt-tolerant through refinement of these crops. The four islands Terschelling, Texel, the Seychelles and Malta are thoroughly investigated as case studies, whereas several other islands are shortly described.

As already mentioned in the introduction above, this research will focus on four aspects which are described in more detail below:

- Improving the use of resources and valuing its ecosystem services *(ecology)*.
- Creating a more self-sufficient food production *(self-sufficiency)*.
- Increasing employment opportunities by stimulating tourism *(economy).*
- Strengthening the islands' identities *(identity)*.

1.5 Methodology

A diverse set of methods are used to write this report which gives, eventually, an answer to the research question. In this research, interviews have been conducted with experts who had relevant information about the topics of interest. Their functions varied from entrepreneurs and saline agricultural farmers, such as Flang Cupido, Hans Wilmink, and a number of farmers from the province of Zeeland, experts from the Wageningen University and from other foreign institutions. The core question for every interview was: do you see the potential of saline agriculture and where do you see this potential? All interviews are retrievable and can be found in the Appendix at the end of this report. Interviews were held in person or by phone. Furthermore, two Wadden Sea islands (Texel and Terschelling) were visited for personal interviews and to investigate the possibilities for saline agriculture ourselves.

Moreover, a literature research has been conducted which helped to set up the scientific framework of this report. In this way, the scientific literature is used to outline the current situation on saline agriculture and its activities on a large and diverse group of (small) islands. To find initiatives that were not documented properly, so-called 'grey literature' was used as well.

1.6 Research scope

In this paragraph, the research boundaries are given both on a time and spatial scale.

Time horizon

A time horizon covering a range from right now to the coming 10 to 15 years has been used to investigate the potential for saline agriculture. In other words, investigations should focus on possibilities that are already right here and could be implemented today. As was stated in paragraphs 1.1 and 1.2, both sea-level rise and land subsidence are crucial causes of salinization, which is currently a problem that has to be dealt with as soon as possible on many islands across the globe. However, it should be kept in mind that one island is suffering more and perhaps sooner already than another island. Therefore, an arbitrary time horizon for the whole world seems inadequate and islands should be analysed separately. Another thing worth mentioning is that time periods beyond 15 years are not being excluded. These are still being used in order to take into account that an even higher necessity to switch to saline agriculture will arise due to the adverse impacts of climate change. Also, this would show a lack of foresight when the welfare of future generations is neglected.

Spatial scale

For this research, the spatial scale is basically unlimited. Islands from all over the world could have made the selection that was held in chapters 4 and 5. The focus, however, was to cover the globe as much as possible and to choose small islands; it was preferred to select single islands from different continents rather than a number of islands from the same continent. The circumstances for the Dutch islands are mapped more extensively in comparison to other islands, due to the reason that for the latter a relatively low number of interviews were conducted.

1.7 Report structure

This report is constituted of multiple elements or chapters, which are together complementary in order to answer the research question that was defined above in the introduction. Chapter 2 ('Salinization and saline agriculture') describes what saline agriculture actually implies, while in chapter 3, the social context of the report is outlined. Chapter 4 ('Exploration around the world') outlines the extent of its practices across the globe. In this chapter, a handful of islands is selected to give an idea of what kind of activities are being done on these specific islands. In chapter 5, four islands are analysed as *case studies* and are being investigated more profoundly. For clarification, these are not the same as the islands dealt with in the previous chapter, but these are cases that deserve to be subjected to a more in-depth analysis to their potential for saline agriculture. Whenever available, information obtained from the conducted interviews is used to discuss an island's potential given the different aspects noted in paragraph 1.4 'Project aim'. Chapter 6 concludes, while chapter 7 gives overall recommendations for islands to both explore and make good use of their potential by giving way to saline agriculture.

2. Salinization and saline agriculture

In this chapter, a literature research is conducted to provide more insight into the extent and impact of salinization. Also, both the nature of saline agriculture and its current situation at the global level are outlined, in which freshwater crops and halophytes are distinguished.

2.1 Extent of and adaptation to soil salinization

As defined in section 1.6, water or soil is classified as salinized when the concentration of salt or chloride particles is too high for an optimal use of, for instance, agricultural production. Salinization, however, is not just limited to the agricultural sector, but the term is also used regarding environmental health (drinking water) and economic welfare (Rengasamy, 2006). Salt-affected soils are everywhere in the world, but the focus still remains on arid and semi-arid regions. No climatic zone is expelled from salinization. To make matters even worse it is expected that salinity levels have been increasing over time due to sea-level rise and land subsidence, threatening food security worldwide. It is especially the coastal regions, including vulnerable islands, that will suffer the most from these impacts (NIBIO, 2017).

In 1974, the FAO together with UNESCO estimated what the situation of salt-affected areas was at that time. They observed that the global total area of saline soils was about 397 million ha while the area of sodic soils was 434 million ha. This comes down to a total percentage of around 6.5 ha of land that is affected by salt. In a more recent report by the FAO in 2000, the total global area of salt-affected soils was about 831 million hectares. To build onto that, FAO's database 'Aquastat' shows that for some countries the area affected by salinity problems can be as high as 50% of the total areas that are fully equipped for irrigation.

It is expected that an increasing soil salinity is causing food security to be threatened on large-scales (NIBIO, 2017). Both in coastal and inland areas of Bangladesh, for instance, a decrease in rice yield of about 15.6% is expected to occur, leading to a lower income of the farmers that are affected. Also in Vietnam coastal areas are suffering from sea-level rise and the concomitant saltwater intrusion (NIBIO, 2017). It is being emphasized by Dr. Udaya Sekhar Nagothu of the Norwegian Institute of Bioeconomy Research (NIBIO) that especially countries like Vietnam and Bangladesh are hot spots for climate change impacts. The reason for this is that Vietnam and Bangladesh are relatively poor countries, having a very little capacity to cope with the loss of property and income (IPCC, 2014).

There is an increasing call for more salt-tolerant rice varieties due to the decline of rice yield. Several farmers in the Mekong delta plus local authorities have reported higher salinity levels in their soil and irrigation waters, causing damages for many as well as loss of livelihoods and income. Dr. Nagothu acknowledges that very few species are able to cope with the high salinity levels. Moreover, salt-tolerant rice varieties are very expensive and, hence, unavailable to many smallholders (NIBIO, 2017). In the light of adaptation, therefore, it seems that there is a high potential for alternative ways of farming. Saline agriculture could be an adequate solution for farmers in areas threatened by high salinity levels. As was noted in paragraph 1.2, Salt Farm Texel is currently exporting their knowledge by implementing a salt-tolerant potato in Bangladesh.

2.2 Types of saline agriculture

Possibilities for saline agriculture exist in various ways. The following three are discussed below: making conventional (freshwater) crops more salt-tolerant, the use of halophytes which are already salt-tolerant by nature, and the irrigation of crops by means of brackish and/or saltwater. The list is not exclusive but is sufficient to provide a set of possibilities that are currently usable.

Freshwater crops and increasing their salt-tolerance

One possibility to realize saline agriculture is by making existing freshwater crops more salt-tolerant, through a process of breeding and selection (University of Lincoln, 2017). In this way, plants could be 'updated' to a version which is more resilient to salinization. Much farmers often think that their conventional crops are not producing well because of wrong cultivation techniques or dry conditions, but these crops suffer most of the time from salinity stress, which goes unnoticed by farmers (Velstra, 23 May 2018, Appendix 22).

Salt Farm Texel is a research centre currently experimenting with a number of conventional crops and their respective salt tolerance. In their *open-air laboratory*, various aspects of salinization and saltwater irrigation related to growth and quality of these crops are being investigated (Salt Farm Texel, n.d.). It was discovered that specific varieties of a handful of conventional crops, such as potatoes, carrots, and cabbage are actually thriving on salinized land (Salt Farm Foundation, 2017).

Regarding the taste of salt-tolerant freshwater crops opinions could differ strongly. However, a Wageningen taste panel tested both a conventional potato and a potato that was made salt-tolerant and came to the conclusion that the latter one was scoring better overall. In fact, salt-tolerant potatoes were found to taste even sweeter than the freshwater crop. A sweeter taste is a result of the fact that some vegetables produce even more sugars in salty circumstances, as a reaction by the plant to counterbalance an increasing saline environment (de Vos, 17 April 2018, Appendix 8).

Salt-tolerance is different per crop species and is dependent on many factors (Stuyt, Blom-Zandstra & Kselik, 2016). In general, most of the conventional freshwater crops tolerate a salt concentration in the irrigation water of about 600 mg Cl^- per litre. Broccoli, peas, and pickle are examples of this category. Crop species like grass, sugar beet, and wheat, however, are much more tolerant to salt and even flourish in an environment containing at least 600 mg/L (Stuyt et al., 2016). On the other end of the extreme, crops such as pepper and lettuce are very sensitive to salt or brackish irrigation water; their threshold is given at a concentration of 300 mg/L.

The case of potatoes is a different story. Although previously it was thought that its particular threshold was between 600 and 900 mg Cl^- per litre, only recently SaltFarm Texel showed that this threshold should be placed at a much higher concentration (De Vos, 17 April 2018, Appendix 8). A salt concentration in the irrigation water of at least 2500 mg/L seems to be more realistic (Stuyt et al., 2016).

Stuyt et al. (2016) do acknowledge that thresholds in salt-tolerance for irrigation water can never be determined with absolute certainty. Uncertainties of instruments and/or distortions in their set-ups give rise to a higher total uncertainty. Some examples of factors on which the salt-tolerance depends are the salt concentration in the root zone, the weather, and the adaptation to soil salinity by crops themselves.

Furthermore, to grow conventional crops on soils with higher salinity levels, one should also take into account that soil salinity affects the soil structure of especially clay soils (van der Zee, 30 April 2018, Appendix 16; Velstra, 23 May 2018, Appendix 22; Rengasamy & Olson, 1991). The reason for this is the poor soil-water and soil-air relationships that are caused by high salinity in these soils (Rengasamy & Olson, 1991). This makes it harder for crops to grow on these soils and it is more difficult to cultivate the soils (Rengasamy & Olson, 1991).

Halophytes

Instead of selecting freshwater crops and making them more salt-tolerant, one could also focus on the use of halophytes. These crops are salt-tolerant by nature and, therefore, do not need any kind of

'breeding and selection' program. Halophytes or *salt plants* are salt-resistant, meaning that they are able to complete their life cycle under saline conditions (Mishra & Tanna, 2017). By using either of two strategies halophytes can adapt to and thrive under conditions of high salinity. One strategy that plants use is *salt tolerance*. An example of this strategy is the excretion of sodium ions, in which excretion, in general, is the process of eliminating waste matter (Flowers & Colmer, 2015). The other strategy is called *salt avoidance* and is illustrated by, for example, the shedding of old leaves that were growing under high salt concentrations (Mishra & Tanna, 2017). When a plant is shedding it allows its leaves (or fruits) to fall to the ground in order to, so to speak, get rid of it. Most of the halophytes grow close to the sea and are frequently being flooded with seawater, such as *Norfolk Samphire* (zeekraal), *Spartina* (slijkgras), and *Suaeda maritima* (schorrenkruid). Halophytes that thrive better in brackish water, such as *Spartina anglica* (Engels slijkgras), *Sea lavender* (lamsoor), and *Sea kale* (zeekool) grow in non-flooded areas that are adjacent to the sea (Zwart, 2012).

There is a high demand from the culinary sector for many halophytes (Cupido & Wilmink, 24 April 2018, Appendix 9; Van der Plaats, 17 May 2018, Appendix 21). On the Wadden Sea islands, for instance, crops are locally produced and placed on the menu of multiple restaurants. Boy Schuiling (17 May 2018, Appendix 19), working as a chef for fish restaurant 't Pakhuus in Texel revealed in a short interview that they prefer to work with local products, such as Norfolk Samphire and Sea kale, rather than using a traditional salad which is normally being served in restaurants. Schuiling argued that they want to make use of the opportunity to promote Texel's own products, something which was also argued for the case of Terschelling by Werner Zuurman, who is a chef at restaurant 'Caracol' (17 May 2018, Appendix 20). Also, it was noticed by Schuiling that the demand for halophytes has been increasing over time and that he expects that it will keep on increasing. The only thing that is holding him back right now from using more halophytes is that these halophytes are only cultivated on a small-scale. When upscaling would occur prices would become lower, making the products more attractive to consumers.

Halophytes will only become successful as crops for the food production, if a number of criteria have been met. First, they must have a high yield potential. Second, irrigation requirements must be within the same range as those for conventional crops and should not harm the soils. Third, halophytes must be able to substitute for conventional crops. Fourth, saline agriculture must play a role within the agricultural sector (Glenn, Brown & Blumwald, 1999). One thing that could help to make halophytes become more successful is by picking them locally, instead of letting these products be imported from places faraway (Cupido & Wilmink, 24 April 2018, Appendix 9). An overview of halophytes that are named in this report is given below in Table 1:

Table 1: Overview of studied halophytes in Latin, English and Dutch, sources: Soortenbank.nl; Wikipedia

Scientific (Latin)	**English**	**Dutch**
Salicornia europaea	Norfolk Samphire	Zeekraal
Limonium vulgare	Sea lavender	Lamsoor
Mesembryanthemum crystallinum	Ice plant	IJskruid
Crambe maritima	Sea kale	Zeekool
Aster tripolium	Sea aster	Zeeaster
Crithmum maritimum	Rock Samphire	Zeevenkel
Mertensia maritima	Oysterleaf	Oesterblad

Brackish irrigation

Another form of saline agriculture is the irrigation of crops by seawater; that is, salt or brackish water. Brackish water irrigation is defined as growing salt-tolerant crops on land that is using (brackish)water pumped from the ocean. It could be one of the solutions to cope with rising global food demand and could decrease the pressure on freshwater resources (Glenn, Brown & O'Leary, 1998). In their research, Glenn et al. (1998) have tested the feasibility of brackish water agriculture. They concluded that it works well in the sandy soils of *desert environments.* A major advantage of using brackish water as an irrigation method is due to its great abundance on Earth: around 97 percent of all the water on the planet is in the oceans (NOAA, n.d.).

For this report, however, brackish water irrigation seems to be of lower relevance for small islands. Not that many islands are located in arid or semi-arid climate zones. However, climate change should not be neglected in such a way that current agro-ecological (climate) zones are to be shifted (Kurukulasuriya & Mendelsohn, 2008). This could also imply that current arid or semi-arid zones could become even hotter and drier. Islands in the Mediterranean, such as Crete and Malta, for example, could be become part of such zones for which brackish water irrigation will be an option.

3. Social context

This chapter is meant to outline the general opinions of all different stakeholders regarding saline agriculture. As described below, these opinions are diverging in some way, thereby reflecting the importance of this paragraph: indirectly giving an overview of the conflicts that have arisen among this topic. The visions of all stakeholders emerged through the interviews that were conducted. For the interviews, the focus has mainly been on the Netherlands due to only a very few foreign leads. Only interviewees from Malta and Crete could be contacted. Therefore, the Dutch situation is outlined in more detail than the foreign circumstances.

3.1 Farmers

On Texel, farmers are still very reluctant when they are asked about a potential transition towards saline agriculture (De Vos, 17 April 2018, Appendix 8). Texel's farmers are afraid that the regional water board stops flushing their land, meaning that the current cultivation of freshwater crops will not be an option any longer. Also, they are afraid that when a neighbour starts with saline agriculture, their land will become saline too (Van Putte, 3 May 2018, Appendix 11). However, according to Jouke Velstra of Acacia Water, this influence is so small that farmers should not worry about this (23 May 2018, Appendix 22).

Farmers are only willing to change their production process when the need to do that is high enough. At this moment, salinization is not that much of an issue for them yet. Saline agriculture is seen as the last possible adaptation method, which should be used only when no other option can be implemented adequately (Van Putte, 3 May 2018, Appendix 11). However, there are already a few pioneering farmers in the province of Zeeland who are dealing with high soil salinity. They are investigating several methods to adapt to this issue. An example is the experimentation with Norfolk Samphire and Sea lavender by Jean-Pierre van Wesemael (1 May 2018, Appendix 13).

Cretan farmers have a similar vision as the Dutch: they still have high revenues with the cultivation of freshwater crops, meaning that they do not want to change (to other crop types or saline agriculture) (Panagea, 24 April 2018, Appendix 18). Their priority lies with the protection of their crops by other measures, such as rainwater harvesting. In Malta, however, it seems that the farmers are already one step ahead. Farmers in the coastal regions are adapting to the saline conditions by using more salt-tolerant crops or halophytes (Buhagiar, 16 May 2018, Appendix 17).

3.2 Federation of Agriculture and Horticulture (LTO)

According to the LTO of Zeeland (ZLTO), the change of further salinization due to saline agriculture and the threat to neighbouring farmers (as stated above) should be investigated more in order to be able to advise farmers properly about it (Van Putte, 3 May 2018, Appendix 11). The ZLTO wants to support farmers who dare to be creative and have new ideas, such as saline agricultural initiatives.
In the Northern part of the Netherlands, the LTO is suspicious about saline agriculture and are lobbying instead for more freshwater resources. Since agricultural profits are simply higher for freshwater crops, the priority for the LTO is to store freshwater as much as possible (de Vries, 19 April 2018, Appendix 4).

3.3 Regional water authorities (Wetterskip Fryslân and Hoogheemraadschap Noorderkwartier)

Wetterskip Fryslân and Hoogheemraadschap Noorderkwartier are responsible for the Wadden Sea islands of Terschelling and Texel, respectively. An important thing to mention is that for both islands it is prohibited to irrigate. At the moment, the focus still lies on keeping the salt water out of the water

systems and to hold onto freshwater resources. However, if there are any initiatives related to saline agriculture the water board has to give in and listen to these ideas (Hamstra, 9 May 2018, Appendix 2). Both water boards can be seen as conservative, in a way that climate change, for example, is not taken into account yet and that the current situation is tried to be maintained as long as possible (Duin, 3 May 2018, Appendix 1).

3.4 Provinces/municipalities (Province of Fryslân plus Aldermen of both Terschelling and Texel)

Saline agriculture is potentially interesting when it is connected to tourism (Van der Wielen, 19 April 2018, Appendix 3). However, Van der Wielen has to acknowledge that saline agriculture would only be an option on a small-scale since Terschelling's agricultural sector is relatively small. Furthermore, saline agricultural projects can be qualified for any subsidy when they meet certain requirements (Satter, 7 May 2018, Appendix 7). A project should, for example, be innovative and contain new knowledge. The vision of the province of Fryslân is to work with water, rather than against it. It listens to any new subsidy requests regarding saline agriculture, but when there are no requests the province will not finance it. Furthermore, it should be noted that the subsidy from the Province for these kinds of projects is generally low. Organisations such as the Waddenfonds subsidize more.

3.5 Entrepreneurs

The difference between farmers and entrepreneurs is that farmers only focus on cultivating crops, whereas entrepreneurs also focus on other aspects of the supply chain. A farmer is regarded as an entrepreneur if it also processes its cultivated products towards a product. In general, entrepreneurs such as Cupido and Wilmink and the farmers from Zeeland are very enthusiastic about their plans regarding saline agriculture. Although their initiatives are still in an experimental phase, their beliefs about whether their projects will succeed are positive. All of them do acknowledge, however, that the market for these products is small, meaning that there is not much room for upscaling in this particular sector. A low supply causes the price to be relatively high (compared to freshwater crops), which is exactly what is need to gain economic benefits from it (Van Wesemael, 1 May 2018, Appendix 13). Receiving a high price for salt-tolerant crops is necessary since cultivating them is a lot of work. This makes it, therefore, expensive to produce (Van Wesemael; Koster, 7 May 2018, Appendix 10; Cupido & Wilmink, 24 April 2018, Appendix 9; De Vos, 17 April 2018, Appendix 8).

4. Exploration around the world

This section describes the specific potential for saline agriculture for a handful of islands, whereby the globe as a whole is tried to be covered by selecting these islands based on their geographical locations. In this way, islands from nearly every region/continent are included in this research. However, the islands that are being discussed in this section are treated as sub-cases due to the limited information that is available about them compared to the four case studies discussed in the next section. Figure 2 shows a general overview of both the case studies and the sub-cases around the world.

The first chosen case study is Terschelling, with its promising saline agricultural initiative of Hans Wilmink and Flang Cupido. The second case study is about Texel, because Texel is home to one of the most important saline agricultural research institutes. The third case study is about the Seychelles, because food security is important there and local authorities are currently actively investigating innovative ideas such as saline agriculture. Lastly, the case of Malta will be investigated. The agricultural sector is important for Malta, but a transition in this sector is crucial in order to keep it a healthy sector.

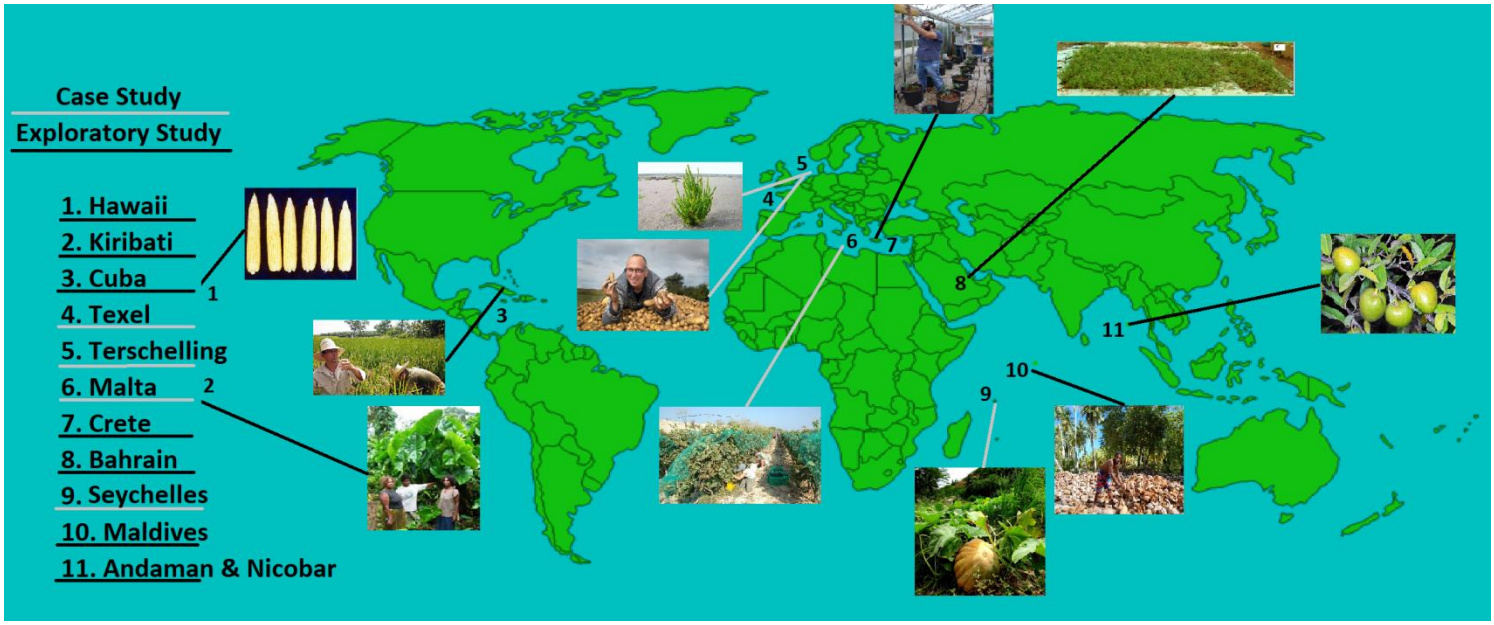

Figure 2: Exploration around the world: overview of all selected islands and their characteristic initiative. (Modified from Oncyclopedia, 2018, complemented by: 1:(College of Tropical Agriculture and Human Resources,2009), 2:(Jackson, 2008), 3:(Hart, 2016), 4:(Marcfoods, 2018), 5:(Stichting Texels Museum, 2017), 6:(Times of Malta, 2009), 7: (Recare Project Information Hub, 2018), 8:(Muchate et al., 2016, p.103), 9: (TODAY, 2015) 10:(Sechelles tourism board, 2018) 11:(Mazza, n.d.)).

4.1 Hawaii

As for many low islands in the world, Hawaii is extremely vulnerable to a host of impacts as a result of climate change (Melillo, Richmond & Yohe, 2014). Rising sea levels will impact small islands the most, causing amongst others damages to agriculture, affecting tourism, and increasing coastal erosion and flooding (Nurse et al., 2014). Currently, sea level rises at a rate of 1.5 millimetres per year. Local sea-level rise, however, is not only dependent on the global average trend but also on local factors, such as geomorphology and oceanographic patterns (Government of Hawaii, n.d.). The impacts of climate change for Hawaii in particular are severe, as the majority of the population, infrastructure, and economic sectors exist on the low-lying coastal plains. Especially these areas are susceptible to

hazards. Like other Pacific Islands, Hawaii will experience a significant higher sea-level rise than the average country (Kopp et al., 2014). This will cause increasing damages to homes and infrastructure, loss of beaches, and endangers habitat.

In 1972 already, a study was conducted by El-Swaify, McCall & Sinanuwong (1972) about soil salinity problems in shoreline areas of Hawaii. The results show that '*most of Hawaii's soils have an excellent drainage, making it easy to apply extra water to prevent salt accumulation in the root zone'*. The issue of 'extra water', however, is that water is becoming less available in the future (IPCC, 2013). Another point that the authors emphasize is that selection of salt-tolerant crops is very important for successful management of salt-affected areas. Coconut, for instance, is important for Hawaii and is a plant with a low water-requirement making it potentially interesting for saline agriculture (El-Swaify et al., 1972).

Another research started by Siegel et al. (1980) on the growth of corn in saline waters on the grounds of the Hawaii Institute of Marine Biology on Coconut Island. Siegel et al. (1980) emphasize the fact that the capability of crops (in this case corn) for growth in highly saline waters is not restricted only to halophytes. Actually, the potential is much higher than was previously expected. These experiments sought to determine the best-qualified candidate for saline irrigation field studies and also for further experimentation.

Eight cultivars of *Zea mays* (corn) plus the so-called 'Hawaiian Super Sweet Hybrid', and the wild species *Zea diploperennis* (a grass species) were used in order to investigate saline tolerance of these crops up to a salinity of 3.2% NaCl. The Hawaiian Super Sweet Hybrid was cultivated by Dr. James L. Brewbaker in 1977. This crop seemed to be very tolerant against saline conditions. Hawaiian Super Sweet Hybrid flowered and produced seed which retained essentially normal viability both in fresh and salt water (Siegel et al., 1980).

In their paper, Siegel et al. (1980) stated that it was expected that in addition to NaCl sea water also contained some trace elements beneficial for crop growth. The observations in this research suggest that *Zea mays* is a good candidate for further physiological study and genetic improvement in the search for crop plants amenable to saline irrigation. Twenty-five years later, many different kinds of Zea mays are developed (HFS, 2015), whereby all of them tolerated salinity decently.

4.2 Kiribati

The Republic of Kiribati, or Kiribati in short, is one of the islands for which climate change is a serious threat (White et al., 2007). Kiribati consists of low-lying coral atolls, in which fresh groundwater in the form of freshwater lenses is the major source of water for inhabitants (Kuruppu, 2009). The survival of the people of Kiribati is determined by both the quantity and quality of this source of groundwater. Groundwater in atolls is affected by the negative consequences of climate change as well as droughts and storms. Droughts are decreasing the thickness of freshwater lenses and increase the issue of salinization in fresh groundwater resources. Also, freshwater lenses are currently being threatened by non-climatic responses, such as rapid population growth and poor governance (White, 1996).

Inhabitants of Pacific islands like Kiribati depend strongly on the freshwater lenses for agricultural purposes. Because of climate change, however, even a small sea-level rise may induce very large reductions in the thickness of freshwater lenses beneath small islands (Bobba et al., 2000).

Besides the use of freshwater lenses as a water source, there are some other sources being exploited on the island of Kiribati. The supply from rainwater tanks and desalinized seawater are two examples of such sources. However, the implication that comes with desalinization is that it requires trained personnel, regular maintenance of the mechanical equipment, and reliable power supplies (White et

al., 2007). Furthermore, freshwater importation is very expensive for small, isolated islands particularly (White et al., 2007).

According to Kuruppu (2009), adaptation measures could offer a window of opportunities to achieve greater water security in the future. In the Kiribati Development Plan 2016-2019, the Government of Kiribati included *Climate change adaptation* as one of the guiding principles of the plan (Government of Kiribati, 2016). In order to mitigate and to adapt to the effects of climate change, several strategies are being implemented. Generally, more programs are to be designed to assist both mitigation and adaptation measures. Also, food security should be enhanced through diversification of crops.

Increasing threats to water security and costly alternative sources of freshwater make Kiribati a highly vulnerable island for climate change. However, it does make the island very interesting for adaptation measures. Saline agriculture could be an adequate way to ensure future food security.

Giant swamp taro (*Cyrtosperma merkusii)* is a crop grown throughout Oceania including the island of Kiribati. The cultivation of this plant (in Kiribati named *babai*) is an important cultural and culinary tradition (see Figure 3). Relatively to other taro species, giant swamp taro is mildly tolerant of saline conditions. However, its cultivation is currently being threatened by sea-level rise, more frequent droughts increasing the salinity of the freshwater lens, and saltwater intrusions (entering the cultivation pit), due to more extreme high tides and coastal erosion (Corlett, 2008). It would be interesting to investigate the possibilities of making the giant swamp taro even more salt-tolerant. This crop has a very high cultural value for Kiribati's identity and for its inhabitants.

Figure 3: Giant swamp taro cultivation on Kiribati (Jackson, 2008).

4.3 Cuba

Soil scientist Orlando Coto stated in an interview with IPS The American that high salinity levels will be a problem in Cuba in the future (Borroto, 2014). Sea level rise caused by climate change is the main factor increasing this threat. As a result, in the dry season in eastern Cuba, a salt layer on top of the soil becomes visible (IPS,2012). The regions around Guantánamo and north of Santa Clara have been experiencing the most saline conditions.

Because Cuba is famous for its avocados, it is crucial that they can still be produced in the future, also under saline conditions. A lot of famous Cuban meals, such as Maduros, Cuban Green Salad with Avocado, Avocado Mojito Smoothie and Creamy Avocado Chicken Enchiladas are focussed on the use of the avocado and determine Cuba's identity. Because avocado is used so much, most people with a garden have at least one avocado tree in their backyard. For that reason, soil scientist Coto studied the commercial and most frequently used Avocado tree in Cuba. In the study, they used "In vitro mutation"

radiation to mutate the trees and test under which salinity conditions they can grow. It turned out that tested species showed higher levels of salt-tolerance compared to regular species (Coto et al. 2014). Plants in saline conditions will develop secondary roots or "aerial roots" which will protect them from high salinity levels (Fuentes et al. 2009). It will take at least seven years to have commercial usable cultivars. The biggest problem for making these avocados commercial is the availability of seedlings. Elaborating on successful tests, more species have been tried. A start has been made making citrus plants more resistant to high salt concentrations. At the end of April 2018, a statement from the Institute of Tropical Fruit Research (IIFT), which is the former institute of Coto, came out claiming they could produce avocado throughout the whole year (14ymedio, 2018). The research about salinity seems to have slowed down with the departure of Coto.

In 1997, a new rice species in Cuba was introduced: the INCA LP-7. This mutant rice variety is a perfect example of succeeded salt-tolerant agriculture. The main driver of the transition was the *Steneotarsonemus spinki*, a mite ruining other rice plants. As stated above, salinization is a big problem in Cuba. The INCA LP-7 could keep up with the salinization in Cuba and already became the most popular species very fast. It stayed popular until this day, which is surprisingly long. Still, twenty years after its introduction, more than a quarter of Cuba's rice is INCA LP-7. Nowadays, other species also resist the mite, but the LP-7 is still used. The transition from conventional to LP-7 was triggered by something else but proved to be resistant to high salt levels too. Therefore, it became a success.

4.4 Crete

The island of Crete is located in the southeastern part of the Mediterranean region and is the largest and most populous of the Greek islands. Most of the population lives on the few plains in the coastal areas. The most important agricultural areas can be found in these regions (Chartzoulakis & Psarras, 2004). Agriculture is the most important sector contributing to the GDP, of which fruit crops and especially olives are the most cultivated. The major water use on Crete is irrigation for agriculture, with around 82% (Recare, 2017).

Mainly due to tourism in summer months, demand for freshwater is often higher than supply. An increase in the exploitation of water resources together with rising sea levels are causing seawater intrusion. As a result, salinization is becoming an increasing problem on the island of Crete, especially in the regions Tympaki, Ierapetra, Falaserna and Palaiochora (Gikas & Angelakis, 2009; Panagea, 2018). Furthermore, according to the IPCC (2013), CO_2-concentrations have been increasing after the industrial revolution, followed by an increase in surface temperature. Moreover, summer precipitation is forecasted to be lower while extreme climatic phenomena, like heat waves, will increase. As a consequence, the combination of less rainfall and an increase in surface temperature will impose higher evapotranspiration losses, increasing the water stress problems of cultivated crops. The reduction in the availability of irrigation water that is of good quality will increase the use of saline water and the already existing problem of salinity on the island even more. Therefore, cultivated species in Crete, and the Eastern Mediterranean region in general, will have to grow in hotter, drier and, in some cases, more saline conditions (Chartzoulakis & Psarras, 2004).

A research by Yeo (1998), however, has shown that the increase in the concentration of CO_2 is very beneficial to plant growth under saline conditions. Since the water use efficiency of plants is expected to increase, less water is being used for transpiration resulting in a reduced salt accumulation in plant tissues. Salt accumulation is being reduced since stomata of the plant do not have to open up that much. In this way, plants are already adapting in a certain manner to climate change. Olive cultivars could potentially be very interesting for cultivation under saline conditions.

Much research is also currently going on in the Timpaki region. Olive trees, horticulture and arable agriculture are most important in this region (Recare, 2017). Especially the irrigation with brackish water is a problem (Alexakis, Daliakopoulos, Panagea & Tsanis, 2018). To make crops more resistant to the use of brackish water, several biological agents, such as the *Trichoderma harzianum fungus*, are currently being tested on for example tomatoes in greenhouses on Timpaki (Panagea, 2017). Figure 4 below illustrates this. However, according to Ioanna Panagea from the KU Leuven, farmers are currently most interested in preventing irrigation with saline water via the rainwater harvesting in greenhouses. Also, no saline agricultural initiatives are currently taking place on Crete (Panagea, 27 April 2018, Appendix 18).

Figure 4: Experiments with Trichoderma harzianum on tomato resistance to saline irrigation in the Timpaki region (RECARE, 2017).

4.5 Bahrain

Not only tropical regions face agricultural problems due to salinization, but also the drier regions have problems. For example, the small archipelago of the kingdom of Bahrain, which is part of the Arabian Peninsula, not only faces problems because of urbanisation at the cost of agricultural land, but also salinization due to poor irrigation water quality from saline aquifers (AQUASTAT, 2008). On top of that, water is scarce in Bahrain and more than 85% is used by the agricultural sector. A transition is, therefore, necessary in the agricultural sector (Jaradat, 2005).

The loss of both agricultural land and its quality threatens the identity of Bahrain, because a lot of native inhabitants are traditional farmers and, currently, a lot of people earn their money in the agricultural sector (AQUASTAT, 2008). The government tries to solve the salinization problem partly via better water management, but other measures are necessary in order to keep the agricultural sector healthy. Saline agriculture can be the optimal solution for Bahrain if practiced on marginal and set-aside lands and when large monocultures are avoided (Jaradat, 2005). For that reason, a lot of research on halophytes is going on in the area at the moment and the Arabian Peninsula is currently regarded as one of the front-runners in bio-saline research (Boer, 2004).

A popular crop in Bahrain of which it is believed to be salt-tolerant is Bermuda grass. Figure 5 shows the increase of salt in water wells in Bahrain between 1941 and 1992. Bermuda grass tolerates salt, but above the critical value of 4 g/L soluble salt in the groundwater, the Bermuda grass performs

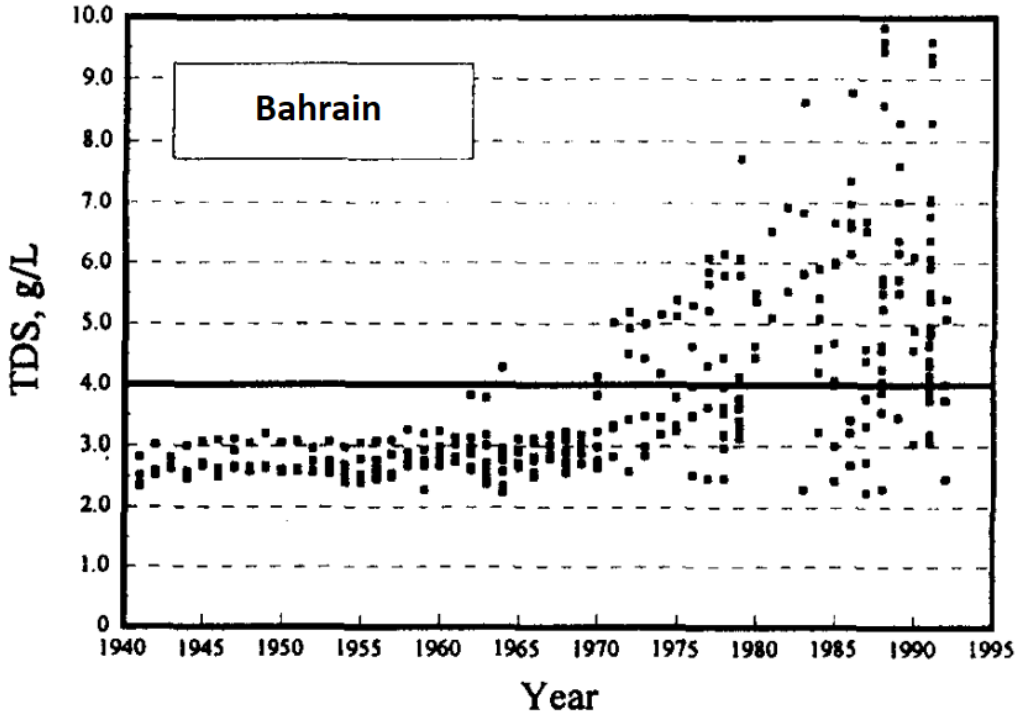

Figure 5: Increase in soil water salinity content in Bahrain over 55 years, with at 4 g/l the critical value for Bermuda grass (Modified from Zubari et al. , 1994, p742).

worse quickly. Along with the increase in salinity, this grass species produced less and less. Another solution had to be found to deal with salinization.

This resulted in the fact that several different halophytes were introduced and used in the region, such as the halophyte vegetable *Sesuvium Portulacastrum*, or Sea Purslane (Boer, 2004). In 2016, an experiment showed enormous potential of this Sea Purslane (Muchate et al., 2016). Not only the yield on a saline soil exceeded the yield on a non-saline soil (Figure 6), the electrical conductivity of soil extract was reduced from 7.1 dS/m to 4.9 dS/m in 90 days. When converted to total soluble salts in g/L, using the conversion method explained by Ullman (2013), these values become respectively 6.0 and 3.1 g/L. Note that these values could vary depending on the type of salt. In just 90 days the Bermuda grass is viable again on this soil. If 90 days make such a large difference, imagine what a few years could do. An entire soil could be cleaned up while keeping production going. After these few years, even salt-sensitive species can be cultivated again.

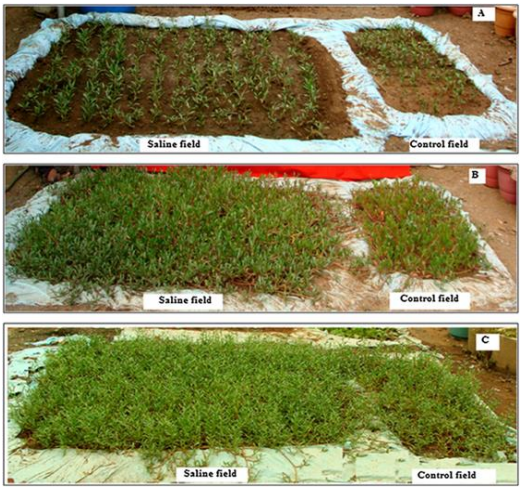

Figure 6: Growth comparison of the halophyte Sea Purslane or Sesuvium portulacastrum in (A) 30 Days, (B) 60 Days and (C) 90 Days in Bahrain (Muchate et al., 2016, p.103).

4.6 Maldives

One of the island countries experiencing salinity problems are the Maldives, which is an archipelago located in the Indian Ocean. The highest point of the country is only 2 meters above sea level. If sea level rises by 2 meters as a result of climate change, the Maldives will be totally flooded (Hoffman, 2007). However, a large number of the islands that the Maldives consist of is located only 1 meter above sea level. If sea level rises by 0.55 meters during the century, as predicted by the IPCC report (2013), inhabitants of most of these islands have to leave (The Sydney Morning Herald, 2012).

Impacts of climate change and sea level rise that this small island state has been facing are, for example, changes in aquifer volume and water quality as saline intrusion increases. Other consequences are the loss of both agriculture and vegetation (Gaffin, 1997; Nurse et al, 1998). Agriculture accounts for 7% of the GDP of the Maldives (The World Bank), whereas tourism is very important for the country's economy (Delta Lab, 2018).

It is estimated that only ten percent of all the land (the soil is sandy type coral soils) on the Maldives has agricultural potential. Some islands have marshal depressions and therefore are suitable for growing Taro crops. Other crops cultivated on the Maldives are watermelon, pumpkin, cucumber, cabbage, cassava, sweet potato, yam, and chilies. After the tsunami in 2004, almost all food crops and fruit trees were lost and could not be saved anymore. Coconuts, however, showed no signs of suffering from the saline floods (FAO, 2005). This, because Coconut trees can survive short periods of very high salinity levels (Foale, 2003). Furthermore, even drought stress is relieved for coconut trees, because they can shortly strive on saline water of half the strength of sea water (Foale, 2003).

Coconut is a basic ingredient in the Maldivian cuisine and is part of the country's identity. It is used in curries, but also in desserts. Especially the mature coconut (*Kaashi*) is used for cooking (Maldives Finest, 2017). According to the Maldivian law, agricultural land cannot be owned by individuals. This results in the fact that the inhabitants feel less responsible for conserving and enhancing the productivity of the agricultural fields. The fields are very small ranging from 100 m^2 to 500 m^2 and the crops are used for subsistence (FAO, n.d.). However, coconut trees can grow on both government areas

and on private or community areas. Coconut is a commercial crop; it is integral to the diet of Maldivians. Moreover, the timber from the coconut trees can be used for construction and boat building. However, the timber species preferred by the Maldivians are becoming increasingly scarce (FAO, n.d.). Because of the uses of the coconut plants and the natural salinity resistance of coconut, it is interesting to investigate the plants further, in order to see whether their period salt tolerance can be increased to a longer period.

Furthermore, Taro plants are a very important staple food in the Maldives and are cultivated in large pits at the edge of swamp areas. Old leaves from former years accumulate in these pits and ensure the fertility of the soil around the Taro plants (Hunter, 2009). When salt water infiltrates the freshwater aquifers, then the salt-intolerant crops, like taro, will not survive the salt intrusion. An option may be to move the agricultural areas further inland. Another option is to switch to salt-resistant crops, but these are expensive and the island inhabitants could lose their island identity (Dodds & Sherman, 2009).

Since a few years, the Maldives area exporting sea cucumber to other countries in Asia. The sea cucumber is claimed to have nutritional and pharmaceutical values. However, there is competition from the local market which makes it difficult to make a profit from it (Johnstone, 2011).

For the reason that the tourism sector is important for the Maldivian economy, coconut is part of the country's identity and is a salt-tolerant plant species. Therefore, it can be interesting to develop products from coconut that can be sold to tourists.

4.7 Andaman & Nicobar Islands

Sea level rise, poor irrigation water quality, and saltwater intrusion are not the only causes of salinization. Natural hazards, for instance, can also cause this specific issue. This is what happened at the Indian Andaman and Nicobar Islands, which do have salinization problems due to climate change, but face even more severe salinization problems in the (upper) surface layers since the tsunami of 2004 (Food and Agriculture Organization of the United Nations, 2006; United Nations Development Programme, 2013).

After the event, it was only partly possible to remove the upper salt layer and neutralize salt affected soils with gypsum (Food and Agriculture Organization of the United Nations, 2006). However, some soils became permanently saline. Therefore, the government provided salt-tolerant seeds, such as millet, to the farmers who were affected. It turned out that the yield after the tsunami with the more tolerant seeds and other intervention methods was as expected and not much lower than normal average yield levels (Food and Agriculture Organization of the United Nations, 2006). This event forced a lot of farmers to cultivate more salt-tolerant crops and shows that it is possible to cultivate crops on more saline land, with good knowledge and some training for farmers. Apart from the risk of natural hazards, the islands face a food supply problem due to population growth, which could also be solved via increasing the agricultural productivity through saline cultivation (Velmurugan et al., 2016). This saline cultivation could be achieved by using wild salt-tolerant relatives of the preferred crops.

An example of a wild relative is the Pond Apple *(Annona Glabra)* which can be used as a rootstock and has crossbreeding options (Figure 7). Many more salt-tolerant options are possible, including Noni, Legume, and Rice (Velmurugan et al., 2016).

Figure 7: A wild salt tolerant Pond apple or Annona Glabra on the Andaman islands (Mazza, n.d.)

Because paddy rice is one of the main cultivators, it is crucial to keep the production high in order to meet the food demand (Velmurugan et al., 2016). Still, 40-50% of the rice paddy cultivars are traditional, while they could be exchanged for salt-tolerant paddy varieties, such as BTS-24 or CARI Dhan-5. A large transition potential still exists.

Other main cultivators are coconut and areca nut trees which together take up 53% of the gross cultivated area (Velmurugan et at., 2016). The interspaces between trees are not used, which makes up 40% of the area. Within these interspaces Cow pea, Pigeon pea or Mung beans could grow, still having 40-60% yield compared to fields where they grow alone. With mixed areas like these, less area has to be desalinated.

The literature suggests that on the Andaman and Nicobar Islands a quick and (partly) successful start of a transition from conventional agriculture towards saline based agriculture can be established (Velmurugan et al., 2016). However, it is just a start towards a more climate-resilient agricultural sector. The potential for a larger transition is high.

5. Case studies

This section contains the more in-depth analyses of four islands that were selected because they met at least one of the following two requirements: there are already saline agricultural initiatives established on the island or there is potential to realise such initiatives. The chosen islands are the two Wadden Sea islands of Terschelling and Texel, the Seychelles located in the Indian Ocean and the Mediterranean island of Malta. In comparison to the islands dealt with in the previous section, these four case studies are profoundly being investigated by means of a comprehensive answer to the research question. The aspects that were described earlier on will be taken into account during these analyses, after which a conclusion is formed regarding the potential of saline agriculture for the specific island. Also, a number of recommendations is given per island.

5.1 Terschelling

The island of Terschelling is the central island of the five Wadden Sea islands. Its surface area is about 86 km² and its population size is somewhat less than 5000 inhabitants (Gemeente Terschelling, 2017). Since 1942, Terschelling has become part of the province of Friesland. Moreover, it falls under the competence of *Wetterskip Fryslân*, which is the regional water authority (Wetterskip Fryslân, n.d.). Figure 8 below shows the island's location on the map.

According to the Central Agency for Statistics (in Dutch often abbreviated as CBS), the island of Terschelling consists only of non-urban or rural area. This is very comparable to the island of Texel, which is the largest of the Wadden Sea islands. What is not comparable with Texel, however, is the relative size of the agricultural area to the total land use. At Terschelling, agricultural land comprises only about 17 percent, while forest and open natural terrain together is by far the largest type of land use on the island (78.4%). In comparison to land use types such as urban and recreational terrain, however, the agricultural area is about fifteen times larger.

Figure 8: Location of Terschelling in the Netherlands (Modified from: Google Maps, 2018a)

Within the agricultural sector there is a low variety in types of agriculture (Van der Wielen, 25 April 2018, Appendix 3). Arable farming is hardly present since the lion share of all farmers has committed themselves to animal husbandry, presumably due to cultural reasons (tradition). A number of dairy farmers deliver their milk to the FrieslandCampina, which is one of the largest dairy companies at the global level (FrieslandCampina, n.d.).

The agricultural sector is one of the core values of the island (Dienst Landelijk Gebied, 2016). Diversification of the types of farming is one of the main characteristics for the sector, implying that along with regular food and milk production also contributions are being made to both meadow birds and landscape management.

Traditional farmers, however, also depend on additional activities to guarantee their own companies' existence. For instance, activities such as agritourism, promoting sustainable energy, and the sales of regional products are a few of which one can think of.

Terschelling is well-known for its *saltmarsh landscape* (Figure 9), which is part of the area that was declared as UNESCO World Heritage in 2009 (Op Terschelling, n.d.). Salt marshes are defined as areas located outside of the dykes, consisting of a large biodiversity. Salt marshes are associated with tidal waves, characterized by circumstances of both low and high tide (Geologie van Nederland, n.d.). The relevance of saltmarshes for this particular case study is that the areas are vegetated with halophytes. Typical saltmarsh species, such as *Norfolk Samphire* (zeekraal), *Sea lavender* (lamsoor) and *Ice plant* (ijskruid), are interesting plants for culinary purposes according to Flang Cupido & Hans Wilmink (24 April 2018, Appendix 9), who are two entrepreneurs in the agricultural business.

Figure 9: Typical example of Terschelling's saltmarsh landscape (Facebook page de Zilte Smaak, 2017).

The demand for regional products is increasing over time, in which the identity of the island is one very important factor. For example, Terschelling is well-known for its local cranberries (Dienst Landelijk Gebied, 2016; Cupido & Wilmink, 24 April 2018, Appendix 9). Tineke Meijer of the local tourist office of Terschelling (VVV Terschelling) says that every cranberry related product is in high demand by tourists (18 May 2018, Appendix 6).

Hydrological situation and salinization

For agricultural purposes, the island depends highly on precipitation in dry periods. Precipitation accumulates in the so-called freshwater lens, which is being replenished in wet periods (mainly winter). According to Nienke Hamstra (9 May 2018, Appendix 2), who is working for Wetterskip Fryslân, there is no water intake taking place by the water board itself. This implies that the only source of freshwater is precipitation for the entire island. However, the current policy applying to this issue states that freshwater retention should happen as much as possible. With regards to the future, this is an important thing to do. Although soil salinity has been increasing for some time now, climate change is even causing salinization to become a greater issue on Terschelling (KNMI, 2015; Hamstra, 9 May 2018, Appendix 2). It is expected that in the lower parts of the island salinization will increase over time because of sea-level rise and land subsidence (KNMI, 2015; de Vos, 2017), especially during the winter season; in dry periods efforts to retain freshwater are higher than in wet periods. Therefore, salinization is higher in winter than in summer. Nowadays, a higher salinity has already been monitored in the ditches at the low-lying locations (Hamstra, 9 May 2018, Appendix 2).

Farmers have had issues with salinization since their cattle depends on freshwater resources as drinking water. Moreover, irrigation by farmers is not allowed at all, implying that the suggestion by Dr. Stuyt (24 April 2018, Appendix 15) to use brackish water for irrigation is not an option for Terschelling. However, laws could change over time. For the far future, one should keep in mind that this situation could change.

Because the low-lying areas have been experiencing increasing salinity in both soils and water bodies, this also does imply that the highest potential for saline agriculture is to be found at these particular locations. The water board acts as a servant when it comes to water demand and supply. It is obedient to the wishes of the water users, meaning that if they would want to switch to saline agriculture the water board would further examine the possibilities to make that possible. It is not, however, an objective of the water board to stimulate saline agriculture in the area. Hamstra (9 May 2018, Appendix 2) emphasizes that they will not be an obstacle in a potential transition, such as a transition that is currently occurring towards more organic agriculture on Terschelling.

Saline agricultural initiatives

At the moment, there is an initiative related to saline agriculture on the island. Flang Cupido and Hans Wilmink, for instance, are very ambitious in promoting agricultural activities related to halophytes in salt marshes located outside of the dykes. Whenever such activities are present in the area these are mainly being funded by revenues from the tourism sector. Besides that, harvests are also sold to local restaurants.

Tineke Meijer of VVV Terschelling thinks that saline activities are highly promising, especially when education about saline agriculture is involved. This could work out positively for the natural and innovative appearance of the island as a World Heritage site (Meijer, 18 May 2018, Appendix 6).

Considering the future perspectives, Cupido and Wilmink are keen to announce that they are planning to set up a *self-picking garden* ('pluktuin' in Dutch). In this 'garden', a handful of different species of halophytes are allowed to be picked and to be taken home by the customers for a certain price. They expect that mainly tourists are very interested to do this, by given them an experience which can be shared when they return home. Hopefully, their story will be widely dispersed which in turn makes others interested too. Eventually, their hope is to also deliver their products to local supermarkets.

Entrepreneurs like Cupido and Wilmink cannot, however, survive without current incoming subsidies from both the province and a European project called 'SalFar'. The former is referred to as the 'Iepen Mienskipfûns', which is Frisian and has been founded to stimulate local, enterprising inhabitants who

have an interesting idea about how the liveability of their particular neighbourhood or city could be improved (Provincie Fryslân, n.d.). Cupido's and Wilmink's project is qualified to obtain a subsidy because of the fact that it meets the following three requirements: the project is original without disrespecting historical developments/events; the project is sustainable; and it unites the community (Wilmink, personal communication, 24 April 2018). The SalFar project is a project which is co-funded by the North Sea Region Programme 2014-2020 (Interreg North Sea Region, n.d.). The project aims to raise awareness about salinization and to offer new methods of farming across the North Sea Region. Moreover, in each participating country, including the Netherlands, so-called 'living labs' experiments are being set up to conduct experiments with the salt-tolerance of crops (Interreg North Sea Region, n.d.). For this reason, the activities of Cupido and Wilmink were funded by the SalFar project. Figure 10 illustrates them celebrating when they received the news that their project was qualified to obtain a subsidy.

Figure 10: Flang Cupido, Hans Wilmink, and others celebrating the news of getting a subsidy for their foundation 'de Zilte Smaak'. (Facebook page De Zilte Smaak, 2017).

Saline agricultural potential

The potential for saline agriculture on the island of Terschelling is still, however, limited. This has to do with the island's geomorphology; the dunes are delivering a large flow consisting of freshwater to the rest of the area, causing the presence of salt or brackish water to be relatively low. However, there are some areas which are very interesting for saline agriculture. These areas are, as already mentioned above, located outside of the dykes. Entrepreneurs, such as Cupido and Wilmink, are already facilitating these particular areas to stimulate the tourism sector by treating these small-farm fields as an 'attraction'. Moreover, according to Nienke Hamstra (24 April 2018, Appendix 2), other locations are qualified for saline agriculture. These are locations where water is being discharged away from the land; that is, being loaded on the sea. At these specific places, the risk of saltwater merging with neighbouring regular agricultural areas water is very low, which is what makes them potentially interesting.

In terms of the economy, it seems that the market is not ready yet for a transition towards saline agriculture. Its operational management is reflected by a relatively high labour-intensity, meaning that more labour (hours of work, number of workers) is needed for one unit of product in comparison to traditional agriculture (de Vos, 17 April 2018, Appendix 8). Jean-Pierre van Wesemael of 'Saeftinghe Zilt', which is a farm in the province of Zeeland, also acknowledges that the cultivation of halophytes requires a lot of handwork and is, hence, very expensive to produce (1 May 2018, Appendix 13). A high

labour-intensity is, therefore, passed on to the price of the product, which is making a salt-tolerant potato, for instance, relatively more expensive than a traditional one. The reason a customer would want to buy the salt-tolerant potato is because of its cultural value; a valuable story behind the production process could help to increase a customer's willingness to pay (Cupido & Wilmink, 24 April 2018, Appendix 9). On top of that, customers are becoming more and more interested in these 'new' products (Schuiling, 17 May 2018, Appendix 19), which are not just used for decoration of the plates, but also due to their incredible saline taste (Van der Plaats, 17 May 2018, Appendix 21).

Still, customers should become aware of the fact that the relevant halophytes are *seasonal vegetables*. This means that they do not grow all year long; in the case of Norfolk Samphire, for instance, the growing season is limited between the months April till September on Terschelling itself (de Vos, 17 April 2018, Appendix 8). Except for the period lasting from April till September, Norfolk Samphire has to be imported from other countries. On the other hand, Cupido & Wilmink argue that the months in which these crops are growing do match very well with tourism's peak season, stimulating the consumption of these halophytes.

It is believed that a country's local market could become self-sufficient in some way. The reason why Cupido and Wilmink started their business in the first place is that they saw Norfolk Samphire that was imported from Mexico and/or Israel on the shelves of the local supermarket in Terschelling. They had the feeling that import of this product was unnecessary since it could just be produced on Terschelling itself. Hence, Cupido & Wilmink took initiative and started their current business. Werner Zuurman of fish restaurant 'Caracol' also acknowledged that picking local products yourself has significant financial benefits (17 May 2018, Appendix 20).

On the one hand, an island can never become completely self-sufficient because of the fact that not every product is naturally present on the island (Roep, 28 April 2018, Appendix 14). It has always been dependent on other countries' resources, implying that import of these products will always be necessary. On the other hand, saline agriculture can stimulate an island's self-sufficiency significantly. Although it will not reach a level at which import is reduced to zero, it can still promote the use of local resources.

The size of an island seems to play a significant role in whether the local market becomes saturated easily. For a smaller island like Terschelling, in comparison to Texel, only one or two suppliers of salt-tolerant products are sufficient to meet the consumers' demand. In that way, only a few farmers have to become convinced to make the switch to saline agriculture in order to create a local economy which is not dependent on other countries regarding these particular products. This was also being acknowledged by Dr. Dirk Roep (28 April 2018, Appendix 14), who is specialized in social transitions in the agricultural sector.

The identity of Terschelling, as discussed above, is mainly reflected by its typical local products, such as the cranberries, and its agricultural landscape including the saltmarshes. The latter is extremely important as habitat for a handful of halophytes, paving the way for a potential transition to saline agriculture on Terschelling. It is especially this kind of areas that have to be exploited in balance with nature and the focus should, therefore, be on halophytes instead of making freshwater crops more salt-tolerant.

Especially due to these factors, the island's identity could be strengthened by making use of this potential and to become one of the pioneers in the production of halophytes. Furthermore, in this case, it also helps that the island is rather small. According to Nils Koster of 'Vlielander Bunkerkaas', located on the Wadden Sea island of Vlieland, the small size of an island makes a local product extra

more important. His 'seaweed cheese' is a great example of such a local product and a typical product from Terschelling can have a similar positive effect.

In short, for the case of Terschelling, we think that the island is not ready yet for a complete transition towards saline agriculture, but there is a high potential regarding appropriate agricultural locations and local resources. Although the economy seems not ready for a shift due to the high production costs of saline products relative to the cultivation of conventional crops, the consumer still wants to pay a higher price when a product has a certain cultural and regional value.

5.2 Texel

Texel is the largest of the Dutch Wadden Sea Islands, located in the North-West of the Netherlands and its location is shown in Figure 11 below. This Wadden Sea island was added to the UNESCO World Heritage Site list in 2009 due to the young dynamical natural forces reshaping the island and its unknown uniqueness in ecological variety (UNESCO, 2009). With its 161 km² surface area and more than 13 thousand inhabitants, it is also the most densely populated Wadden Sea island of the Netherlands (CBS, 2011). Compared to the Netherlands in general, Texel has a relatively big agricultural sector. The land area used for agriculture is 63%, while 29% is used for forest and open nature area. This leaves only 8% for traffic, recreational and urban areas, compared to the 16% Dutch average (CBS, 2011).

Figure 11: The location of Texel (Modified from: Google Maps, 2018b)

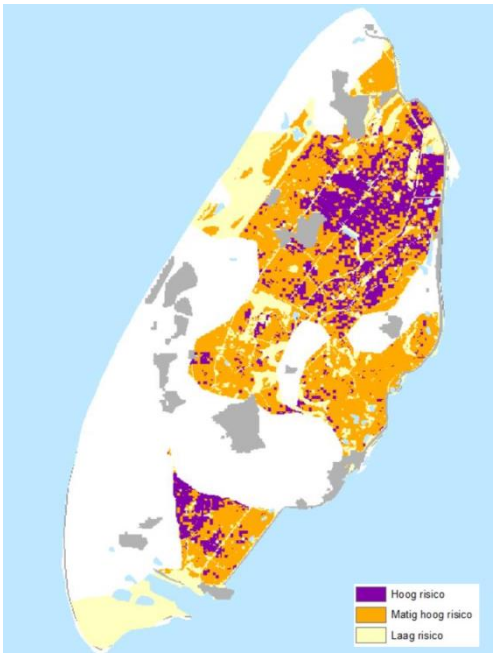

Figure 12: Provisional version salinization risk for Texel for the current situation based on the thickness of the freshwater lens. Hoog risico = High risk, Matig hoog risico = Medium high risk, Laag risico = Low risk (Acacia Water, 2018)

Climate change and hydrological situation

Wind and water waves coming from the North Sea towards Texel are increasing in height in the future due to climate change (Hoozemans, 1990). The dominant wind direction is south-west, so salt water will reach Texel. Climate change also affects sea level rise, the sea will be 0.4 till 1.05 meter higher by 2100 (Katsman et al., 2011). This higher sea level combined with drier summers will result in a thinner freshwater lens on the island (Van der Zee, 30 April 2018, Appendix 16). If the freshwater lens is thin, more brackish water will infiltrate into the root zone (Acacia Water, 2018). Particularly, for an island

as Texel, sea level rise is also regarded as a very important threat to current salinity levels (Velstra, 23 May 2018, Appendix 22). Figure 12 shows the salinization risk for Texel, based on the current situation regarding the freshwater lens.

Texel is an island without big freshwater resources, so freshwater is precious (Schreijer et al., 2012). Salt water floods could cause a decreased productivity of agricultural lands for ten years. Flood damage costs greatly exceed the costs needed to prevent this flood damage (Schreijer et al., 2012). Pumping up freshwater from the dunes and irrigating by water from ditches is prohibited by law. Texel mainly consists of two areas: the old land and the Eierland polder. In the old land (south-east), relatively more freshwater is present, while in the Eierland polder the salty water lies closer to the land surface. This results in a higher salinization risk as can be seen in Figure 12. According to Velstra, the 'Prins Hendrik polder', which is part of the old land, is already quite saline and has a high risk of salinize even further (23 May 2018, Appendix 22). This also applies to some of the polders located in the north. The western part of the island consists of coastal dunes which form a barrier between continental and marine habitats (Van den Berg, 2017). Most of the freshwater comes from within these dunes, but in long and dry periods this reservoir is depleting.

Hydrological climate adaptation measures
To keep up agricultural production, several anti-salt water strategies are used already (Schreijer et al., 2012):

- To conserve the freshwater lens, irrigation is prohibited
- Manipulation of the freshwater bubble location by changing water level in ditches
- Inlet of effluent water coming from sewage treatment plants

Taking these measures, Texel is a formidable example of climate adaptation in the form of water management. Despite these measures, the precipitation deficit is still between 150 and 200 mm in the period April to September for an average year, which will, in unfavourable climate scenarios, increase to more than 300 mm by 2050 (Schreijer et al., 2012). Over the whole year, however, Texel experiences a precipitation surplus (Velstra, 23 May 2018, Appendix 22), which implies that the deficit originated in summer is being offset in the other seasons.

Hoogheemraadschap Hollands Noorderkwartier gives several methods with which the quality of the current groundwater will be kept steady, which mainly includes the improvement of previously mentioned strategies (Schreijer et al., 2012). One alternative approach to keep the water from becoming more saline is an extra measure: the prohibition of ploughing or manipulating the land deeper than 12 centimetres. This leads to more extensive land use, preserving the freshwater lens. Although, this could delay the salt water problem for some years, this does not completely solve the problem. The second alternative approach the Hoogheemraadschap thinks might be plausible in the future is the use of saline agriculture. This approach has two main prerequisites: the costs of water management should decrease and the saline water should be completely sealed off from the neighbouring freshwater agriculture.

Current initiatives and market potential
Salt Farm Texel is currently one of the best examples of adaptive saline agricultural initiatives (Figure 13). Marc van Rijsselberghe the main developers of the Salt Farm and Arjen de Vos is one of the main researchers of the farm. Besides producing vegetables, another goal of the Salt Farm is to gain new knowledge about saline agriculture, for which the farm is famous around the world (17 April 2018, Appendix 8). The Salt Farm Texel has successfully found the most salt-tolerant conventional crop type, for species such as potatoes, for which the technology has been exported to Pakistan and Bangladesh.

Special halophyte products like Norfolk Samphire and Sea lavender are produced as well. These products can be considered as luxury products because the crop weight to farmland ratio is not optimal. These products are sold with outstanding packaging and some extra small gifts. This is confirmed by Koster of Vlielander Bunkerkaas (Figure 14), who produces seaweed cheese (7 May 2018, Appendix 10). His cheese is unique in the world, so there is demand. However, it is very labour-intensive to produce this cheese. Selling it as a special premium product will overcome this high producing costs.

Figure 13: The Salt Farm Texel with a bird eye view (Netherlands Water Partnership (NWP, 2018).

Figure 14: Seaweed cheese by Vlielander Bunkerkaas (Vlielander Bunkerkaas, 2018)

De Vos thinks there is more room for saline agriculture, but nowadays this is restricted to the luxury segment or niche markets. Islanders from Texel will not regularly buy expensive products when this is not necessary. De Vroede from VVV-Texel thinks the niche market has potential as well because most of the tourists like special products they have not encountered yet, such as halophyte vegetables (12 April 2018, Appendix 5).

Van Rijsselberghe, who is famous for his potatoes (Figure 15), sells luxury packages of silt vegetables and provides just as Koster a nice example of a special premium product. He also thinks that adding a story to special island products could convince people to buy these goods. In the richer countries like the Netherlands, there is a market for more expensive local products (De Vos, 7 April 2018, Appendix 8). Texel has mostly jobs in micro and small-scale jobs compared to other parts of the Netherlands (CBS, 2011). Therefore, with all these opinions combined, it is commonly agreed that on islands like Texel small-scale agricultural projects will fit better.

Tourists do buy special products in restaurants, but will not cook meals with the saline products themselves. Tourists could be visiting the salt producing farm as a tourist attraction. After having seen a strange halophyte in a restaurant, tourists could go and see the farm where they were produced. One of the restaurants offering halophytes is 'T Pakhuus. In this restaurant, they use Norfolk Samphire as a salt replacement. The chefs like to use other saline vegetables too, but off-season this is not always possible since the saline vegetables get very expensive (Schulting, 17 April 2018, Appendix 19). Chef Van der Plaats of restaurant Vincents Eilandkeuken is confronted with the off-season problem as well. They have a philosophy of only using local products, so the menu is varying enormously during the year (17 May 2018, Appendix 21). Because of this vision, tourists are very interested in the story behind the food served. Due to interests of tourists, journalists and scientists the VVV-Texel sees the potential of saline agriculture on Texel.

Although if looked from the identity point of view, the relatively large island Texel, has already a strong identity as more factors determine this identity. For example, everybody knows the Texel sheep, so it is not expected that one extra regional product will increase the identity enormously. Saline agricultural products could be a nice extra addition though.

Figure 15: Marc van Rijsselberghe with his famous salt potatoes (Marcfoods, 2018).

The saline transition

De Vos thinks farmers have several reasons for being suspicious towards saline agriculture. The first reason is the lack of knowledge, which creates a vicious circle. On the one hand, the farmers do not know about saline agriculture and, therefore, are not interested in saline crops seeds. On the other hand, the seed companies, therefore, do not offer such seeds wherefore the farmers never learn about these salt-tolerant plant seeds. The second reason is the fear for the opinion of other farmers. The subject is still quite unknown, the effects on the surroundings are uncertain and saline agriculture has a negative connotation among farmers. Potential saline farmers do not want to anger or provoke their neighbours, so they do not start saline agriculture. The third reason for farmers being suspicious towards saline agriculture is the uncertainty of making profits. The low sales value of saline vegetables is not attractive; it is hard to make a profit. A good example here is the Salt Farm, which despite selling its vegetables, is still dependent on subsidies. De Vos is, however, planning to be self-sufficient in the future. One of these subsidies is provided by the Waddenfonds. Not every saline farmer, however, gets funded. To get such a subsidy, one should be innovative and should gain new knowledge (Satter, 7 May 2018, Appendix 7). The Waddenfonds has a vision to work with rather than against water where possible, so they do not necessarily support or oppose saline agriculture.

According to Van der Zee, a professor at Wageningen University & Research in the department Soil Physics and Land Management, literature about saline agriculture is too unstructured to work with, especially for farmers (30 April 2018, Appendix 16). Salt problems on Texel will not increase noticeably within the coming ten years to cause an active transition to saline agriculture. It is difficult to separate fresh from saline water, so only isolated areas where traditional agriculture is very difficult, are suited. Currently, it is cheaper to keep the water fresh and sell conventional crops than to make a transition. This is because new halophyte crops are less profitable than conventional crops in general. We think that if you are able to adapt financially interesting crops that tolerate higher salinity levels, you might be able to switch to marginal crops and make a higher profit out of it.

Alderman of Texel De Vries thinks that saline agriculture in this decade on Texel only has a chance as a supplement, not as a replacement of conventional agriculture. Farmer associations like LTO are suspicious about saline agriculture. Saline agriculture does not necessarily make the situation of salinization better or worse, but it lowers the care for saline water. This could endanger surrounding freshwater properties which makes it a tough decision for a farmer to switch because of possible angry neighbours. Using isolated or end of the line properties could resolve this issue. This is confirmed by

Duin of the Hoogheemraadschap Noorderkwartier (3 May 2018, Appendix 1). The water board will not facilitate saline water for the farmers; if they want to do saline agriculture they should choose a spot where saline water already is available. The farmers are allowed to grow saline crops, but as long as the farmers can avoid saline conditions, they will do so. They just make way for higher profits using marginal crops. Knowledge of making saline agriculture viable is still lacking. Polder Walderburg was given back to nature ten years ago due to salinity and there was no chance for the polder to become saline agricultural land. Nobody even proposed it, because nature was at that point more important for the tourism sector. Other environmental problems seem larger than salinization, the potential for biological agriculture or a solution for the phosphate deficit are more necessary. On a longer timescale, the transition to saline agriculture might be necessary, but this is not attractive on municipality scale yet.

Saline agricultural potential

The potential of saline agriculture in terms of economy, ecology, identity, and self-sufficiency on Texel depends mainly on the size of the problem of salinization. Salinization problems exist, but can be overcome currently and will be overcome within the scope of the timeframe of a decade used in this study. Although it is not a problem yet, it is commonly agreed that salinization due to climate change will cause a problem in larger time frames (50 till 100 years). Because of this potential problem in the future, it is wise to gather knowledge and do experiments like going on now on Texel. Islands are especially suited for doing experiments like this because of their isolated water cycle.

Producing saline crops in the form of salt-tolerant conventional crops and “newer” halophyte crops is an option. The production of halophyte crops still has a few weaknesses, the first one being relatively labour-intensive. Halophyte crops do not produce enough mass, causing the profits to be relatively low. The halophyte products are interesting for a niche market combined with a large seasonal dependence, making a large-scale transition difficult due to market saturation. This niche market, however, could be the perfect opportunity for small projects like the Salt Farm. Restaurants already using the products increase to present the products to the tourists. When introduced to these products, tourists can participate in organized trips to the salt farm which increases general wealth among the island.

Salt-tolerant conventional crops have other market problems as they are often out produced by their traditional equivalents on freshwater properties. Because of the irrigation prohibition on Texel, it is hard to produce these freshwater equivalents such as on the mainland.

A large-scale transition would be difficult anyway because it is very radical and hardly reversible. Farmers might not want to collaborate because of the following three reasons: they do not have the knowledge, they are scared to disturb their neighbours, and it is doubtful whether they make enough profit without being subsidized. However, according to Velstra, farmers should not be afraid to disturb their neighbours, because saline agriculture can be done next to conventional agriculture and the risk of salinizing the neighbouring land is very small (23 May 2018, Appendix 22). In the current situation, it is cheaper to keep the water fresh.

On Texel, creating an extra strong identity is very difficult because the island already has a strong identity. The scale of the projects will be too small relative to the island’s size. This being said, however, the saline crops do contribute to the total island identity.

The project of Salt Farm Texel has drawn a lot of media attention about the potatoes, exporting their knowledge. They clearly took a step into a leading position on saline agriculture in the world. Tourists are already coming to the island, and saline agriculture is a nice extra addition to the total of offered

tourist attractions. In each case, saline crops have an indirect effect when bought by tourists in restaurants. In this way, tourists will value the time more they spend when having dinner.

In the coming decade, the potential for saline agriculture regarding the economy, ecology, identity, and self-sufficiency is low to moderate in our opinion, but there is a niche for small entrepreneurs. Because of longer scale climate change it is wise to gather knowledge and prepare for the times this potential increases.

5.3 Seychelles

One of the island countries that has salinity problems is the Seychelles located in the Indian Ocean (see Figure 16). The Seychelles is an archipelago with an area of 460 km^2. It is a sovereign state in the Indian Ocean counting around 95.000 inhabitants of which 90% lives on the main island Mahé (WPR 2018). Most of the islands on the Seychelles are granitic islands, though there are also a few coral islands. Mahé, Praslin, Silhouette and La Digue are the largest granitic islands and cover an area of around 235 km^2. These islands, together with nearby small ones, are called the *Inner Islands*. Around 99% of the population of the Seychelles lives on the inner islands. (Skerrett & Disley, 2016; SPA, 2018).

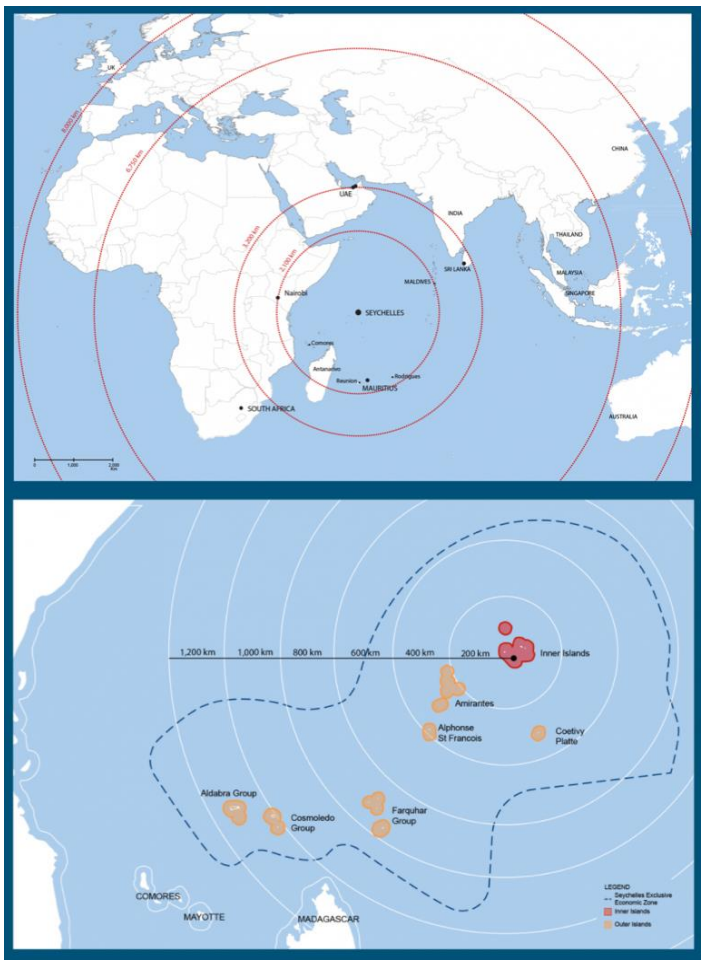

Figure 16: Maps of the Seychelles. Above: Location relative to the world. Below: Location of the inner and outer islands. (SPA, 2018).

The *Outer Islands* are situated beyond the Seychelles plateau and are hardy visited by any other than scientists, volunteers, and tourists (SPA, 2018).

Food security is important for the Seychelles. Food security and sovereignty is a high priority as 72% of the food consumption on the Seychelles is imported (Meriton-Jean, 2014). The mission of the

Seychelles Agricultural Agency is to achieve 80% of the local production of fruits and vegetables in order to create a higher level of food security for a good, healthy and productive Seychelles. While, at the same time, keeping a preserving eye on the pristine environment and biodiversity (SSA, 2018). Although 72% of the food is imported, the country should, according to the available arable land and the resources, be capable of producing for its own inhabitants plus the tourism population (NAR, 2010). However, it is due to consumer preferences that the Seychelles are highly dependent on food imports for imported stapled food (e.g. rice), instead of the locally produced staples. According to Hendriks & Maleebo (2009), it is not an actual shortage of food availability on the island, but rather a lack of recognition of the richness of food resources which are locally available. Hence, only a change in consumer preference could be sufficient to solve the food security issue.

Problems within the agricultural sector

Characteristic for the agricultural sector on the Seychelles is mixed farming on mainly small family farms (FAO, 2005). The agricultural sector contributes for less than 3% of the total GDP. Compared to the agricultural sector, tourism is a crucial sector for the Seychelles, because it generates employment and economic activity. The tourist sector contributes with 70% to a major part of the total GDP. There are conflicts over land use between agriculture and tourism and also conflicts over water shortages between agriculture and tourism (ASCLME, 2010). Agricultural lands are used not only for the local market; the Seychelles also have some export products. A traditional export product of the Seychelles is cinnamon (ASCLME, 2010). The FAO (2005), however, states that the cinnamon exportation has been declining since the 1970s. Cultivation of cinnamon is expensive and there is strong competition from other countries.

One of the problems during practicing of agriculture is the use of highly saline groundwater to irrigate crops in the coastal areas of the island. Due to an increase in soil salinity, yield losses of vegetables are experienced (CBA, 2016). Sometimes crops fail because of the soil salinity, but the salinity is not alarming in its current stage. However, in the future, this could become worse because of seawater intrusion as a consequence of sea level rise (NAS, 2017). Although salinity levels are not alarming currently, most crops in the coastal regions of the Seychelles are affected by salinity. The salinity level in the soil varies due to rainfall and freshwater usage (TODAY, 2015).

Initiatives

An initiative on the Seychelles related to saline agriculture is carried out on the field of farmer Roy. Roy runs a one-hectare farm in Praslin on the Seychelles. He produces amongst others pumpkins, watermelons and tomatoes and adapts his crop selection according to what he learned from monitoring salinity (see Figure 17). Roy followed a training in choosing crops depending on the salinity level of the soils, organized by the Seychelles Agricultural Agency (SSA) and Dubai-based International Centre for Biosaline Agriculture (ICBA). The report from Cedras (2015) describes the activities performed for this Soil Salinity Project.

Figure 17: Pumpkins produced by Roy on saline soil. (TODAY, 2015).

For this project, remote sensing equipment was installed to increase monitoring of salinity levels of the soil. Also, farmers, SAA technicians, and Extension Officers were trained, as illustrated in Figure 18, to increase their capacity to access and utilize climate information. Also, during this project, salt tolerant seeds were acquired (Cedras, 2015).

The training also includes methods to reduce soil salinity by crop rotation with crops that remove salt from the soil (TODAY, 2015). Using a table that classifies the crops that can be cultivated under various salinity levels helps farmers to choose the right crops and to maximize their productivity and income. Salinity levels are measures by soil sensors as is shown in Figure 19. There are currently five sensors on Mahé and Praslin (TODAY, 2015). Another method demonstrated in the same training is the use of 'gypsum', a fertilizer containing calcium sulphate, which regulates the amount of sodium and magnesium in the soil (see Figure 19). This method is already used by farmers on the Mahé and Praslin. (NAS, 2017).

The document from the UNDP (2016) describes another project in which the local farmers are provided with means to increase their production by reducing freshwater shortages experienced in the dry season. The aim was to provide farmers with water tanks for rainwater harvesting and irrigation equipment and to carry out reforestation to preserve water catchments (ecosystem-based approach). Also, farmers on Praslin learned new techniques to combat saltwater intrusion and to reduce soil

Figure 18: Farmers are trained in practicing agriculture under saline conditions (CBA, 2016).

Figure 19: Soil sensors that measure salinity levels on Mahé (CBA, 2016).

salinity. A financial contribution of farmers to the equipment was successful, as it increased capacity and created a sense of ownership. The project had a positive impact on the food production of the concerned farmers due to the increased water storage (UNDP, 2016).

The Seychelles Strategic and Land Use Plan 2040 (SSLUP), provides a framework for future development and spatial planning in the long term. This plan balances the necessity for economic growth and development against protection of nature. The vision highlights the importance of integration of land use, transport, and environment to be more resilient to future challenges. (SPA, 2018).

Saline agricultural potential

On the Seychelles, there is demand for the development of the saline agricultural sector, as the government aspires to produce 80% of the fruits and vegetables locally (SSA, 2018). Since salinity poses a threat to agriculture and therefore food security, practicing saline agriculture is a necessity. Currently, several projects for dealing with salinity in the agricultural sector are going on. The focus of these projects is on adaption to salinization of the soils. Adaptation measures are: adapting crop selection based on salinity level of the soil, reducing soil salinity by crop rotation with crops that remove salt and rainwater harvesting to combat salt intrusion (UNDP, 2016; TODAY, 2015).

Since the tourist industry is crucial for the economy of the Seychelles and a major part of the identity (ASCLME, 2010), it is recommended to connect saline agriculture (especially halophyte cultivation) and tourism. On Texel and Terschelling, for instance, saline agriculture is focused on tourism already by organizing activities for tourists and by selling locally produced products with a story. In that sense, saline agriculture could fortify the tourist's experience on the islands (Cupido & Wilmink, 24 April 2018, Appendix 9). Applying this strategy, which is called agritourism on the Seychelles, could attenuate the conflict between agriculture and tourism (ASCLME, 2010).

Both products that are produced with resources typically coming from local (saline) agriculture and that are coupled to the tourist industry could strengthen the local economy and employment (Leigh & Blakely, 2016). An example of such a product is seaweed soap or samphire soap, which includes ingredients of saline crops in the soap (Gunning, 2016). A farmer from the Netherlands already produces soap and cosmetics with samphire or other halophytes, as shown in Figure 20 (Janse, 1 May 2018, Appendix 12). Samphire can be used for medicinal application and is a nutrient-rich dietary source (Kang et al, 2011; Ksouri et al, 2011). The soap can be produced by local employees, which increases the local employment opportunities, and with local resources (Bolwijn, Kranen & Van der Wauw, 2016). Typical Seychelles' soap could be presented in luxury hotels and sold in souvenir shops, which now is already done with cinnamon cosmetics shown in Figure 21. A disadvantage of this kind of use of saline crops is that it is used for cosmetics instead of nutrition, which means it will not enhance food security.

When producing halophytes during the tourist season, the crops can be used for restaurants and touristic activities. However, during the low season, there will be remnants as the demand for saline crops is expected to be less. In that case, these remnants can be used for products with a longer storage life than when using the crops for nutritious purposes, such as glasses and soap. For example, Samphire (*Salicornia europaea*) is a halophyte high in soda and burning of this plant releases sodium. The ash of halophytes can be used for the production of glass when the ash is fused with sand (Gunning 2016), because the high salt content of the ash lowers the melting point of glass (Liebezeit, Künnemann and Gad, 1999).

Figure 20: Cosmetics produced with Samphire in the Netherlands (Laurence, 2018).

Figure 21: Cosmetics produced with Seychellois cinnamon (Laurence, 2018).

The production of glasses and glass sculptures could be interesting on the Seychelles. To make products successful, it is necessary to brand these as a luxury product with a typical design and an interesting background story (De Vos, 4 April 2018, Appendix 8; Cupido & Wilmink, 24 April 2018, Appendix 9; Van Wesemael, 1 May 2018, Appendix 13; Roep, 30 April 2018, Appendix 14). Offering these glasses as design products that are exclusively available from the Seychelles will contribute to this branding. In Figures 22 and 23 respectively, examples of sculptures and goblets from Scott Bisson are given. This pieces of art capture the beauty of nature in the glass, which in addition could draw more attention for nature conservation. Coupling such kinds of typical glass to the identity of the island is expected to make the products very likable for tourist to take home.

Figure 22: *Blue Rippleback Turtle* (Scott Bisson, 2018).

Figure 23: Frog Goblet (Scott Bisson, 2018).

Another way of coupling saline agriculture with both tourism and food security is by organizing touristic excursions to saline crop plantations, producing local delicacies for restaurants and host cooking classes (Cupido & Wilmink, 24 April 2018, Appendix 9). In this way, the saline crops are used for nutrition and the products will have a higher added value, which will give even higher profit.

There certainly is potential on the Seychelles regarding the increase of its self-sufficiency and in supporting the tourism industry. The people of the Seychelles are aware of the fact that action is

necessary to address increasing soil salinity. From an ecological point of view, saline agriculture seems to be possible on the islands, since farmers already cultivate crops in a more saline soil. However, to make saline agriculture economically attractive for farmers, we recommend to couple agriculture with tourism and develop new products and activities related to saline agriculture. When producing products in line with the characteristics of the island, these products could strengthen the countries identity.

5.4 Malta

Malta is a country located in the Mediterranean Sea with around 420.000 inhabitants. The country is an archipelago, consisting of three large islands, Malta, Gozo, and Comino (see Figure 24). Only these three largest islands are inhabited, the smaller islands are untenanted. The total surface area of the country is 316 km2, of which 32.3% is agricultural land. (CIA, 2017). Agriculture contributes for only 1.4% of the total GDP (World Bank, 2016). On the contrary, as on most islands, the tourist industry in Malta is a major component of the economy. The total contribution of tourism to the GDP of Malta is 27% (WTTC, 2017).

Malta's highest point lies around 253 m, while the lowest point is equal to the level of the Mediterranean Sea: 0 m (CIA, 2017). The flora on Malta is typical for a low lying coastal region in the Mediterranean. Halophytes, like Glasswort and Seablite, are mainly found in salt marshlands. On the low-lying rocky coasts of the country, Golden Samphire, Rock Samphire, and Sea lavenders are found (Briguglio & Busuttil, 2018).

Figure 24: Map of the country of Malta (CIA,2017).

Problems in the agricultural sector

Malta is a country with low freshwater resources per person (Malta Water Association, 2015). Groundwater is pumped up too much to be naturally recharged. As a result, the freshwater aquifers are declining and saline sea water can invade and therefore enhance the salinity of the available water (Malta Water Association, 2015; Buhagiar, 16 May 2018, Appendix 17.). This is a problem for farmers in Malta since they are forced to irrigate their crops with other sources of water or to revert to

desalinisation, which leads to additional costs (Malta Water Association, 2015; Buhagiar, 16 May 2018, Appendix 17).

Furthermore, some of the land in Malta is below sea level, so seawater can infiltrate easily into the sewer system and salinize the water that is used in the agricultural sector. Moreover, the water in the sewer system is salinized by hotels that use reverse osmosis to desalinize water and dispose the leftover salty water into the sewer system (Buhagiar, 16 May 2018, Appendix 17). Also, hotels flush their toilets with salty water that ends up in the sewer system as well. Due to over-abstraction of groundwater and due to saltwater intrusion, a significant amount of irrigated land is already salinized, especially in the Pwales valley (Hallet, Sakrabani & Thompson, 2017).

As a consequence of extracting more freshwater from the aquifers than can be recharged, the seawater will replace the freshwater, which means an increase in salinity of the groundwater (Spiteri, Scerri & Valdramidis, 2015). This process is shown in Figure 25. The salinity keeps increasing as a consequence of uncontrolled human activities (Scicluna, 2015). Farmers notice changes in the water they extract to irrigate their crops with. David and Mary Mallia run an organic farm on Malta and experience higher salinity since rainfall has become less (McGrath, 2007). Especially during summer, the water is more saline and farmers like David and Mary face salinity problems (Buhagiar, 16 May 2018, Appendix 17).

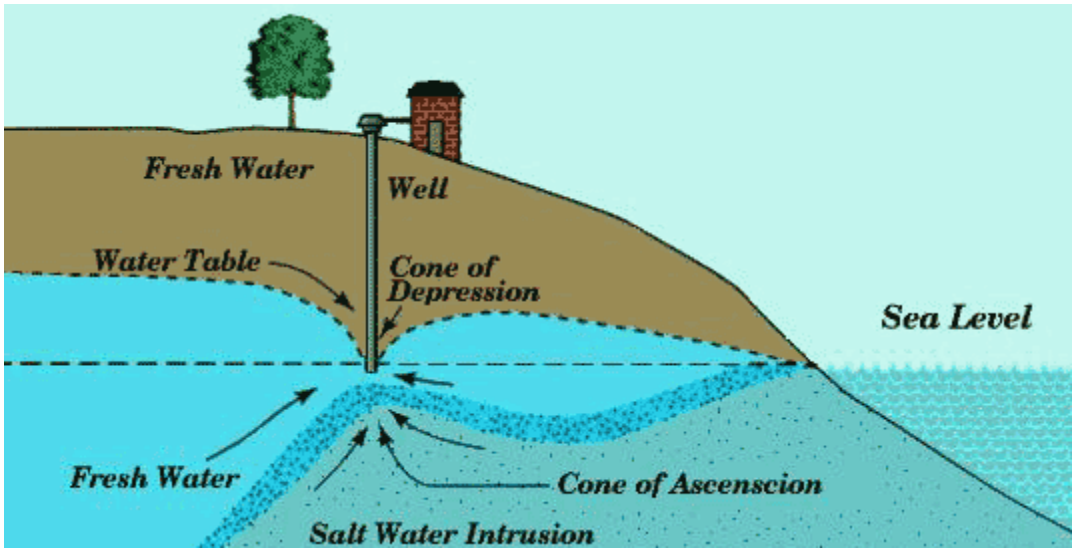

Figure 25: Salt water intrusion as a consequence of freshwater extraction in coastal regions. Retrieved on 24 May 2018, from: https://laulima.hawaii.edu

Apart from the salinity problems, the agricultural sector faces problems on the socio-economic level. When Malta joined the European Union (EU) in 2004, protective measures such as levies and quotas on import food expired and Maltese farmers faced a sudden competition for imported food with other countries in Europe. Cheaper imports caused the interest in local foods to be reduced (Vella, 2017; Buhagiar, 16 May 2018, Appendix 17). Both the accession to the EU and the salinization of the soils are a source of concern to the inhabitants of Malta because the country inclines to become fully dependent on foreign imports (Vella, 2017). Also, agriculture is a main component of the Maltese tradition and therefore of the identity of the country. Farmers are the ones who maintain the island's agricultural landscape and the ones who produce local delicacies (Vella, 2017).

The competition with Europe and the varying yields make the agricultural sector an unstable source of income with low profits. As a consequence, young people are no longer interested in working in the

agricultural sector, as demonstrated by the average age of farmers being 55 (Vella, 2017), as illustrated by Figure 26. In contrary, young people are interested in working in the tourist sector, as this generates a more stable and higher income and has a fancier image than farming (Buhagiar, 16 May 2018, Appendix 17). The decreasing number of young farmers and farmers in general decreases the self-sufficiency of the island because more products are imported than before (Buhagiar, 16 May 2018, Appendix 17).

Figure 26: The average age of farmers is high in Malta (Chetcuti, 2015).

Initiatives

Currently, agriculture in Malta is practiced by farmers of an average age of 55, as already said. Since most farmers produce on small-scale, the farmers are able to focus on growing fresh vegetables with a fuller flavour than industrially farmed vegetables (Jung, 2017). To stand out, some farmers started to produce purple cauliflower, yellow watermelon and local zucchini (Vella, 2017). Another initiative is the eco-farm, which enables farmers to sell their products directly to consumers (see Figure 27). This intends to increase awareness of the quality and taste of locally produced food in comparison to importing food and intend to give farmers a better return on their crops (Vella, 2017).

Figure 27: A Maltese eco-farm, selling crops directly to consumers. Source: Vella (2017), by James Bianchi/Media Today.

Since the salinity problems are biggest near the coast, some farmers that have their fields located near the coast were forced to adapt to the saline conditions. They chose crops that are more salt tolerant, such as barley and crops from the Amaranth family. Barley has a relatively high salt tolerance and grows uninhibited till an upper limit of 10 g chloride per litre of water (Stuyt, Blom-Zandstra & Kselik, 2016).
If farmers grow halophytes, these crops are only for personal use (Buhagiar, 16 May 2018, Appendix 17). Agriculture for commercial purposes is mainly conventional agriculture with crops that tolerate higher salinity.

When wastewater treatment plants treat water from the sewage system, the clean water is still salty. Most farmers refuse to use brackish water for irrigation since they believe it will damage crops and soil structure. The government of Malta invested in two treatment plants that treat water in order to make it less salty. This treated water is called 'second class water' or 'new water' (Times of Malta, 2018; Buhagiar, 16 May 2018, Appendix 17). The farmers using this new water are reporting better yields. The new water provides a more stable supply of water with low salinity, resulting in higher production flexibility (Times of Malta, 2018). The initiative is also beneficial in a way that it diminishes the stress on the aquifers since groundwater abstraction is minimized.

Saline agricultural potential
The core of the problem in the Maltese agricultural sector seems to be a combination of salinization and the negative image of farming. It is important to make agriculture as an occupation more attractive to young people. The rising gap between old farmers and the new generation is an opportunity to develop a new, trendy and profitable form of agriculture. An innovative idea such as saline agriculture might motivate young farmers to choose a farming career. However, the trendy image for saline agriculture needs to be developed, which takes time. Therefore, at first sight, the potential for saline agriculture seems to be not that big. A few farmers are forced to adapt to more saline conditions, but outside the areas with saline conditions no saline farming is practiced.

However, it could be interesting for Malta to use more salt tolerant crops (conventional crops) in the agricultural sector because then the crops can be irrigated with more brackish water. In that case, the extremely expensive treatment plants are not necessary.

It is very important to motivate younger people for the agricultural sector in general since otherwise no successors will take over the farms. Giving (saline) agriculture a trendy image seems the way to make younger enthusiastic for the agricultural sector. Since those young people are also very interested in the tourist sector, it might be effective to diversify and connect the farms to the tourist sector. The tourist sector, namely, has the image of generating good money. Tourism should not be seen as an alternative, but as a complementary activity that provides a more stable income.

As stated by Sharpley & Sharpley (1997), the countryside itself is what attracts people for rural tourism. A rising agritourism sector could be created by, for example, building a bar on the farm, where people could have a drink when visiting the countryside. Also, a restaurant with local (saline) products and delicacies could be very interesting for tourists. Expanding rural tourism fits into the plans of Malta to direct in the direction of rural tourism (Government of Malta, 2012). However, to create the necessary trendier image of the countryside it is advisable to also offer more active, fast and modern activities such as trail biking, windsurfing or off-road motor vehicle riding (Grech, 2014).

Since tourists who visit the rural areas are most of the times interested in interaction with local community and culture (Government of Malta, 2012), offering a full holiday on the farm could be an

idea. This could be combined with helping a few hours per day on the farm and in exchange teach the tourist about (saline) farming, cooking, and culture (see Figure 28).

Figure 28: Tourists help picking grapes in return for a wine tasting experience in the countryside. Source: Times of Malta (2009).

Our results suggest that the potential for saline agriculture is definitely present on Malta. Saline agriculture has potential in respect of innovation of the younger generation, tourism, and irrigation with brackish water. In the field of ecology, economy, and identity, you could say that the agricultural sector in Malta is on a tipping point. Conventional farming appears to be hindered by salinization, though farmers show no interest for cultivation halophytes or saline crops. Producing with saline irrigation water is not under discussion yet. Also, there is no market for halophytes and saline crops yet. As long as possible, the farmers search ways to sustain conventional farming. For now, the 'second class water' seems to be the desired adaptation measure. However, this low saline water could be the stepping stone towards full saline agriculture. In the field of economy, the agricultural sector goes through rough times. Farmers have an unstable and relatively low income, which makes it an unattractive career for the younger generation. Therefore, it is important to increase the economic prospects of farming by diversification and coupling to the tourist sector. Since agriculture surely is a major component of the Maltese identity, it is worthwhile to preserve the agricultural sector and convey the importance of this sector to tourist by giving them insight in the Maltese culture, kitchen and agricultural practices.

6. Conclusion

During the research, it became evident that a clear difference exists between conclusions for the short-term and conclusions for the long-term. Therefore, this concluding section (and the subsequent recommendations section), will be divided in both short-term outcomes, which concerns the coming 10-15 years, and long-term outcomes, which concerns a far-future vision.

Short-term

For this moment, it can be concluded that many islands around the world have salinity problems already. Currently, on several islands, many investigations are carried out on what the best adaptation method(s) might be. On most islands, saline agriculture is one of the last used adaptation methods for salinization issues and is only interesting for farmers when no other option is possible. For farmers, it is simply too hard to transition towards saline agriculture due to multiple reasons. Firstly, because there is still much unknown about which crops are salt-tolerant and how the soil structure is affected by high salinity levels. Secondly, practicing saline agriculture is highly labour-intensive and thus, expensive. Thirdly, in the case of saline agriculture, it is not possible to use the area for conventional agriculture anymore. Lastly, the demand for a complete transition towards saline crops or products is too low at this moment.

Farmers, water boards, Provinces, and other local authorities first try to keep the saltwater intrusion as minimal as possible and use other technologies, such as rainwater harvesting. If these measures turn out to be insufficient to practice conventional agriculture any longer, the interest in saline agriculture increases. Furthermore, at this moment, saline agriculture has potential already as a special niche market for tourists and should be developed further in this way.

With regards to the economy of an island, saline agriculture can be especially interesting for the tourist sector and when newly gained knowledge can be exported to foreign countries. The tourist industry profits indirectly, because it is expected that tourists will not come for saline products on an island in the first place. However, both halophyte cultivation and the products that are processed from it make the surroundings, restaurants, and shops on islands more attractive for tourists. Furthermore, thanks to the tourists, farmers might be able to start a small saline agricultural business already next to their regular business and expand this in the far future. The success of Salt Farm Texel shows that the second option is already interesting for an island's economy. Internationally, considerable interest in saline agricultural knowledge exists. Texel, has become, as a consequence, well-known for this knowledge.

For the ecology of the island, developing saline agricultural initiatives can be beneficial. The reason for this is that touristic self-picking gardens (containing halophytes) increase the natural diversity and can be regarded as a safe haven for several species, thereby guaranteeing their existence. Moreover, many farmers and the water boards are currently afraid that if saline agriculture becomes integrated in the agricultural sector, surrounding non-saline agricultural parcels and natural areas will become saline as well. This influence, however, will be really small and will not form a threat for the surrounding areas. It is, therefore, at this moment, very important that the involved parties are made aware of this fact in order to circumvent this misapprehension.

It will be difficult to increase the self-sufficiency of islands by exploiting the saline agricultural niche on the short-term. Simply because at this moment the supply is too low for an island to really depend on it. On top of that, at this moment, local inhabitants do not have saline crops in their daily diet. Inhabitants should, at this point, be made aware of the fact that saline crops are a seasonally product that can be included in the diet in order to increase the self-sufficiency of the island. This could be seen as a preparation towards a more self-sufficient island on the long-term.

The identity of an island will not be changed in a couple of years. However, especially on islands where the tourist sector is very important (such as Malta and the Seychelles), it is interesting to develop and sell special regional products. Especially on smaller islands (Terschelling as compared to Texel) these special regional products can strengthen the identity already on the short-term.

Long-term

For the long-term, it is expected that the salinization on islands will increase due to climate change. Therefore, it is crucial to expand and develop the already existing saline agricultural niche in the future. This should happen on multiple fronts, so that saline agriculture can increase both the self-sufficiency and food security of islands.

In the long run, it is important that conventional crops, which are slightly adapted in a way that they are more salt-tolerant, become available for farmers. The reason for this is that several islands have been experiencing freshwater shortages during droughts already and this shortage will increase even more. Whenever it is possible in such a situation to irrigate with slightly brackish water, droughts will affect crops less. It is also interesting to develop the saline agricultural research on islands even further, such that islands will become hot spot locations on this particular topic. On top of that, this knowledge could become a valuable export product for islands.

Furthermore, in the far future one should make sure that the balance between nature and agriculture should be preserved. At this moment, some areas are simply too saline for conventional agriculture. If there is no other purpose for these areas, they are often changed into nature reserves. The procedure of assigning another land use to such areas, however, should be done carefully. When saline agriculture is further developed and be established on a larger scale, namely, a chance exists that these areas become interesting for the (saline) agricultural sector, which will come at the expense of the nature reserves.

As already stated, saline agriculture increases the self-sufficiency of an island. When local inhabitants would prefer local saline products, these will be consumed more, in turn increasing the demand. As a consequence, saline products are not only interesting for the tourist branch anymore. If the saline agricultural niche on an island further develops, it is even possible to export saline products. In this way, a re-trade can be realised with the mainland, in the case of Texel and Terschelling for instance, or with other places in the world. Thus, as opposed to the short-term, saline agriculture can become important for the self-sufficiency of islands in the future.

On the short-term, as stated above, it is expected that the special regional products will only mean something to the identity of (small) islands from a tourist's perspective. However, in the long run, when saline agriculture becomes more important for islands from both an export and self-sufficiency point of view, it is expected that saline agriculture becomes important for the identity of islands. On some islands, however, the agricultural sector is really important already for their identity (on Malta for example). Due to the introduction of saline agriculture on a larger scale, the agricultural sector in general will change and this might be hard to accept for island inhabitants.

7. Recommendations

After this research, several recommendations have been formulated, which are generally valid for all investigated cases. However, it should be kept in mind that every island is different and not every recommendation concerns every island. Furthermore, as already stated, the recommendations will be divided in short term recommendations (for the coming 10-15 years) and recommendations for the far future (15 years and beyond).

Short term

- Introducing saline agriculture on islands is only interesting on a large-scale if no other adaptation options are available, but introducing this type of agriculture on a small-scale has potential already.
- Small-scale saline agricultural projects with halophytes are easier to establish and interesting for the tourism industry.
- On small islands, the tourist identity can be strengthened when local saline products, which attract tourist, are developed.
- Local inhabitants should be informed about the potential of saline products as a preparation towards a future situation in which the island becomes more self-sufficient.
- Involved parties should be made aware of the fact that saline agriculture does not affect neighbouring land parcels.
- Islands can increase their international notoriety by becoming an experimental garden and exporting saline agricultural knowledge to other countries.
- On islands where the economy mainly depends on the tourism industry, it is recommended to couple agriculture with tourism (agritourism), in order to reduce conflicts between agriculture and tourism and to get the highest profits out of saline agricultural products.

Long term

- The already existing small-scale saline agricultural niche market should be further developed and upscaled in order to increase the self-sufficiency of islands.
- Saline agricultural products should become an export product for islands.
- If it is allowed to irrigate on islands, brackish water irrigation on slightly more salt-tolerant crops can reduce damages caused by droughts.
- Brackish water irrigation could potentially be interesting for islands which become located in a climate zone (arid or semi-arid) that is appropriate for this type of irrigation.
- It is important to keep in mind that a healthy balance between nature and agriculture should be maintained, especially when saline agriculture provides more opportunities for agriculture in nature reserves that were assumed to be unsuitable before.
- If the saline agricultural sector becomes larger, it will become important for the identity of an island and islands can become famous for these special products on long time scales.

8. References

14 ymedio (2018, May 2). Cuba Hopes To Grow Avocados Year-Round With New Planting System. Retrieved on 16 May 2018, from https://translatingcuba.com/cuba-hopes-to-grow-avocados-year-round-with-new-planting-system

Acacia Water. (28 May 2018). Notitie Verziltingsrisicokaart voor Texel (versie 0.9)

Advance Africa. Figure retrieved on 23 May 2018, from https://advanceafrica.co.za/project/viability-assessment-of-commercial-production-of-wild-harvested-cinnamon-in-the-seychelles/

Aquastat. (2005). Irrigation in Africa in figures – AQUASTAT Survey 2005. Source found on 13-04-18: http://www.fao.org/nr/water/aquastat/countries_regions/SYC/SYC-CP_eng.pdf

Aquastat, Land and Water Division, Food and Agriculture Organization of the United Nations. (2008). Country information Bahrain. Rome, Italy. Retrieved on 12 April 2018 from, http://www.fao.org/nr/water/aquastat/countries_regions/BHR/

Alexakis, D. D., Daliakopoulos, I. N., Panagea, I. S., & Tsanis, I. K. (2018). Assessing soil salinity using WorldView-2 multispectral images in Timpaki, Crete, Greece. Geocarto International, 33(4), 321-338.

Agulhas and Somali Current Marine Ecosystems, ASCLME (2010). Coastal Livelihoods in the Republic of Seychelles. Retrieved on 13 April 2018, from https://iwlearn.net/resolveuid/3305deea3724548e9155b93e4313f99f

Bisson, S. (n.d.). Blue Rippleback Turtle. Retrieved on 17 May 2018, from http://www.symmetrygallery.com/bisson/520-blue-rippleback-turtle

Bisson, S. (n.d.). Frog Goblet. Retrieved on 17 May 2018, from https://www.crystal-fox.com/?Cat=1554.

Bobba, A. G., Singh, V. P., Berndtsson, R., & Bengtsson, L. (2000). Numerical simulation of saltwater intrusion into Laccadive Island aquifers due to climate change. *Journal of the Geological Society of India. Bangalore*, *55*(6), 589-612.

Borroto C.G. (2014), The Cuban context for agriculture and innovation, Handbook on Agriculture, Biotechnology and Development chapter 14, pages 190-202. Retrieved on 12 April 2018, from https://www.elgaronline.com/view/9780857938343.00019.xml

Boer, B. (2004). Halophyte development in the Gulf Arab countries-UNESCO Doha's activities 2001-2003. Tropical Ecology, 45(1), 187.

Bolwijn, M., Kranen, H., Van der Wauw, W. (2016). De laatste zeep van Aleppo. *De Volkskrant*. Retrieved on 14 May 2018: https://www.volkskrant.nl/kijkverder/2016/zeep/

Briguglio, L. & Busuttil, S. (2018, 17 May). Malta. *Encyclopaedia Britannica*. Retrieved on 23 May 2018, from: https://www.britannica.com/place/Malta#ref23498

Buhagiar, J. (2018, 16 May). Phone interview. Appendix 17.

CBA. (2016). Increasing the resilience of farming communities on the Praslin plateau by addressing soil salinity to boost local food production.

CBS (2010). Gemeente op maat: Texel.

CBS (2011). *Terschelling*. Retrieved on 30 April 2018, from https://www.cbs.nl/nl-nl/publicatie/2011/50/terschelling

Cedras, A. (2015). Soil Salinity Project, Annex E, final report. *Local CSO*.

Chartzoulakis, K., & Psarras, G. (2005). Global change effects on crop photosynthesis and production in Mediterranean: the case of Crete, Greece. *Agriculture, ecosystems & environment*, *106*(2-3), 147-157.

Chetcuti, G. (2015, July 13). A day in the life of a Maltese farmer. *Independent*. Retrieved on 22 May 2018, from: http://www.independent.com.mt/articles/2015-07-13/newspaper-lifestyle culture/A-day-in-the-life-of-a-Maltese-farmer-6736138782

Church, J.A., Clark P.U., Cazenave A., Gregory J.M., Jevrejeva S., Levermann A., Merrifield M.A., Milne G.A., Nerem R.S., Nunn P.D., Payne A.J., Pfeffer W.T., Stammer, D. and Unnikrishnan A.S. (2013). Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CIA. (2007). The world fact book – country comparison to the world. *Central Intelligence Agency*. Retrieved on 23 May 2018, from https://www.cia.gov/library/publications/the-world-factbook/geos/mt.html

CIARI (2015) Annual report-2014-15. Central Island Agricultural Research Institute (CIARI), Port Blair, pp 16–17

College of Tropical Agriculture and Human Resources (2009). University of Hawai'i - Retrieved on 28 May 2018, from https://www.ctahr.hawaii.edu/hfs/

Corlett, G. (2008). *Tuvalunacy, or the real thing?* Retrieved on 18 April 2018, from http://insidestory.org.au/tuvalunacy-or-the-real-thing/

Coto O., Rodríguez N.N, Fuentes J.L, Alvarez A., Machado M., Santiago L., Zamora V. and Ramos-Leal M., (2014), Mutagenesis: exploring genetic diversity of crops, Chapter 13, pages 265-282.

Cupido, F. & Wilmink, H. (2018, April 24). Personal interview. Appendix 9.

Dam Roy S., Velmurugan A., Zamir Ahmed S.K., Nagesh Ram, Kiruba Sankar R., Sankaran M., Gautam R.K., Swarnam T.P., Shrawan Singh (2015). Island agriculture: perspective and strategies.

Dam Roy, S. et al. (eds). National seminar on harmonizing biodiversity and climate change: challenges and opportunities, 17–19th April. CIARI, Port Blair, pp 1–21

De Kempenaer, J. G., Brandenburg, W. A., & van Hoof, L. J. W. (2007). *Het zout en de pap: een verkenning bij marktexperts naar langeretermijnmogelijkheden voor zilte landbouw* (No. 07.2. 154). InnovatieNetwerk.

Delta Lab. (2018). Maldives Matter. *TU Delft*.

De Vos (2017, 31 March). Verzilting als kans voor Nederland. *Friesch Dagblad.* Retrieved on 16 May 2018, from http://www.frieschdagblad.nl/index.asp?artID=72710

De Vos, A. (2018, 17 April). Personal interview, Appendix 8.

De Vries, P. (2018, 19 April). Personal interview. Appendix 4.

De Vroede, Y. (2018, 17 April). Personal interview, Appendix 5.

De Zilte Smaak Facebook page (2017). Retrieved on 28 May 2018, from https://scontent-ams3-1.xx.fbcdn.net/v/t31.08/20424133_1421567214596631_2983655809977821_o.jpg?_nc_cat=0&oh=cddd3abf1b8a393da6b1c0fb65f7daa2&oe=5B7BA60D

De Zilte Smaak Facebook page (2017). Retrieved on 28 May 2018, from https://scontent-ams3-1.xx.fbcdn.net/v/t31.08/17436334_1284087755011245_4688297132947749791_o.jpg?_nc_cat=0&oh=e1ccf92f945179dcb603a3afbba18680&oe=5B7AB860

Dienst Landelijk Gebied (2016). Natura 2000-beheerplan Terschelling (4). Retrieved on 1 May 2018, from https://www.synbiosys.alterra.nl/natura2000/documenten/gebieden/004/beheerplan/terschelling%20beheerplan.pdf

Dodds, F., & Sherman, R. (2009). Climate Change and Energy Insecurity:" The Challenge for Peace, Security and Development". *Routledge*.

Duin, M. (2018, 3 May). Phone interview. Appendix 1.

Flowers T. J., Colmer T. D. (2015). Plant salt tolerance: adaptations in halophytes. Ann. Bot. 115, 327–331. 10.1093/aob/mcu267

Foale, M. (2003). *Coconut Odyssey: The Bounteous Possibilities of the Tree of Life*. Australian Centre for International Agricultural Research.

Food and Agricultural Organization (1974). Soil map of the world. UNESCO: Paris.

Food and Agricultural Organization. (2005). Irrigation in Africa in figures – AQUASTAT Survey 2005. Retrieved on 13 April 2018: http://www.fao.org/nr/water/aquastat/countries_regions/SYC/SYC-CP_eng.pdf

Food and Agricultural Organization. (2005). Maldives Post-Tsunami Agriculture Brief. Retrieved on 12 April 18, from http://www.fao.org/ag/tsunami/assessment/maldives.html

Food and Agriculture Organization of the United Nations, regional office for Asia and the Pacific. (2006). Rehabilitation of agriculture in tsunami affected areas in India: one and a half years later. *Report of the regional workshop on rehabilitation of agriculture in tsunami affected areas: one and a half years later.* Bangkok, Thailand.

Food and Agricultural Organization. (n.d.). Fact sheet: The Maldives – Women in Agriculture, Environment and Rural Production. Retrieved on 12 April 2018, from http://www.fao.org/docrep/007/ae543e/ae543e02.html

Fuentes, J.L., Santiago, L., Rodríguez, N.N., Coto, O., Alvarez, A., Valdés, Y., Vernhe, M., Guerra, M., Altanez, S., Prieto, E.F., Velázquez, B., Rodríguez, J.A., Sourd, D.G., Fuentes, V.R. and Ramos Leal, M., 2009. Combining zygotic embryo culture and mutation induction to improve salinity tolerance in avocado (Persea americana Mill). In: Induced mutation in tropical fruit trees. IAEA-TECDOC-1615. IAEA, Vienna, Austria, pp. 71-82

Gaffin, S.R. (1997): Impacts of Sea Level Rise on Selected Coasts and Islands. *The Environmental Defense Fund*, New York, NY, USA, 34 pp

Gemeente Terschelling (2017). *Algemene informatie Terschelling*. Retrieved on 30 April 2018, from https://www.terschelling.nl/t-actueel/het-eiland-terschelling_43187/item/algemene-informatie-terschelling_30131.html

Geologie van Nederland (n.d.). *Kwelder en kreekrug*. Retrieved on 1 May 2018, from http://www.geologievannederland.nl/landschap/landschapsvormen/kwelder-en-kreekrug

Gikas, P., & Angelakis, A. N. (2009). Water resources management in Crete and in the Aegean Islands, with emphasis on the utilization of non-conventional water sources. *Desalination*, *248*(1-3), 1049-1064.

Glenn, E. P., Brown, J. J., & O'Leary, J. W. (1998). Irrigating crops with seawater. *Scientific American*, *279*(2), 76-81.

Glenn, E.P., Brown, J.J. & Blumwald, E. (1999). Salt Tolerance and Crop Potential of Halophytes. *Critical Reviews in Plant Sciences*, 18:2, 227-255. DOI: 10.1080/07352689991309207

Google (2018a). Retrieved on 28 May 2018, from https://www.google.nl/maps/@52.8503647,5.7085367,8.88z

Google (2018b). Retrieved on 28 May 2018, from https://www.google.nl/maps/@52.8503647,5.7085367,8.88z

Government of Hawaii (n.d.). *Sea level rise.* Retrieved on 19 April 2018, from http://climateadaptation.hawaii.gov/sea-level-rise/

Government of Kiribati (2016). Kiribati Development Plan 2016-19. Retrieved on 18 April 2018, from http://www.mfed.gov.ki/sites/default/files/Kiribati%20Development%20Plan%202016%20-%2019.pdf

Government of Malta. (2011-2012). *Tourism Policy for the Maltese Islands 2012-2016*. Retrieved on 22 May 2018, from https://secure2.gov.mt/tsdu/downloads/tp12-16.pdf.

Grech, T. (2014). Malta's potential to develop rural tourism. *Institute for tourism, travel and culture*.

Gunning, D. (2016). Cultivating Salicornia europaea (marsh samphire). *Dublin, Ireland: Irish Sea Fisheries Board*.

Hallett, S., Sakrabani, R., Thompson, A., Deeks, L., & Knox, J. (2017). Improving soil and water management for agriculture: insights and innovation from Malta. Journal of Applied Research & Practice, MCAST.

Hamstra, N. (2018, 9 May). Phone interview. Appendix 2.

Hart, N. (2016). International development correspondent Retrieved on 28 May 2018 from https://www.iaea.org/newscenter/news/cuban-rice-variety-bred-for-tolerance-to-salinity-and-rice-mites-stays-relevant-in-cubas-fields-and-its-cuisine-for-almost-20-years

Hendriks, S. and N. Meelobo. (2009). Workshop report "Seychelles Food Security" – Pillar III under MTDF and UNDP Funding. Republic of Seychelles.

Hoffman, J. (2007). The Maldives and Rising Sea Level. *ICE Case Studies*, 206.

Hofman & Paalman (2014). *Rainwater harvesting, a sustainable solution for urban climate adaptation?* Nieuwegein, the Netherlands: KWR Watercycle Research Institute.

Hoozemans F.M.J., (1990). Long term changes in wind and wave climate on the North Sea, The Dutch Coast: Paper No.3.

Hunter, D. (2009). Maldivian Homegardens – A stable farming system in a fragile environment. *Permaculture Research Institute.*

Instituto de Investigaciones de Fruticultura Tropical (IIFT) La Habana, Cuba https://www.wageningenacademic.com/doi/pdf/10.3920/978-90- 8686-796- 7_13.

Interreg North Sea Region (n.d.). Retrieved on 18 May 2018, from http://northsearegion.eu/salfar/

Interview IPS: Mutant Fruit Trees to Grow in Saline Soils in Cuba (2012). Retrieved on http://www.ipsnews.net/2012/12/qa-mutant-fruit-trees-to-grow-in-saline-soils-in-cuba/

IPCC. (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp

Jackson, G.V.H. (2008). Retrieved on 21 May 2018, from https://cropgenebank.sgrp.cgiar.org/index.php/crops-mainmenu-367/other-crops-regeneration-guidelines-mainmenu-290/major-aroids-mainmenu-406

Janse, H. (2018, 1 May). Phone interview. Appendix 12.

Jaradat, A. A. (2005). Saline agriculture in the Arabian Peninsula: Management of marginal lands and saline water resources. In *Journal of Food, Agriculture & Environment.* (pp. 302 -306).

Jung, S. (2017). Malta's outstanding local produce. Retrieved on 16 April 2018, from https://www.airmalta.com/destinations/malta/blog/detail/malta-outstanding-local-produce

Johnstone, E. (2011). Coconuts and sea cucumbers main course for Maldives agriculture. *Minivan News.* Retrieved on 12 April 2018, from https://minivannewsarchive.com/environment/coconuts-and-sea-cucumbers-main-course-for-maldives-agriculture-27088

Kang, S., Kim, D., Lee, B. H., Kim, M. R., Chiang, M., & Hong, J. (2011). Antioxidant properties and cytotoxic effects of fractions from glasswort (Salicornia herbacea) seed extracts on human intestinal cells. *Food Science and Biotechnology*, *20*(1), 115-122.

Katsman, C.A., Sterl, A., Beersma, J.J. et al. (2011). Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta—the Netherlands as an example. *Climatic Change* 109: 617.

KNMI. (2015). KNMI'14-klimaatscenario's voor Nederland; Leidraad voor professionals in klimaatadaptatie. KNMI: De Bilt, 34 pp.

Kok, A. (2006). Salinization above sea level on the Dutch Wadden Islands. In *Paper SWIM-SWICA conference Sardinia (Italy).*

Kopp, R. E., Horton, R. M., Little, C. M., Mitrovica, J. X., Oppenheimer, M., Rasmussen, D. J., ... & Tebaldi, C. (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future*, *2*(8), 383-406.

Koster, N. (2018, 7 May). Phone interview. Appendix 10.

Ksouri, R., Ksouri, W. M., Jallali, I., Debez, A., Magné, C., Hiroko, I., and Abdelly, C. (2011). Medicinal halophytes: potent source of health promoting biomolecules with medicinal, nutraceuticals and food applications. Critical Reviews in Biotechnology, DOI: 10.3109/07388551.2011.630647

Kurukulasuriya, P., & Mendelsohn, R. O. (2008). How will climate change shift agro-ecological zones and impact African agriculture?

Kuruppu, N. (2009). Adapting water resources to climate change in Kiribati: the importance of cultural values and meanings. *Environmental Science & Policy*, *12*(7), 799-809.

Laurence, J. (2018). Seychelles News Agency Retrieved on 28 May 2018, from http://www.seychellesnewsagency.com/articles/3904/French+aromatherapist+creates+Seychelles+Yi-King+brand+of+essential+oils+using+ancient+Chinese+methods

Liebezeit, G., Künnemann, T.D., & Gad, G. (1999). Biotechnological potential of North Sea salt marsh plants – a review of traditional knowledge. *Journal of biotechnology*, *70*(1-3), 77-84.

MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1613-1654.

Maldives Finest. (2017). Maldives hit by coconut crisis. Retrieved on 12 April 2018, from https://maldivesfinest.com/coconut-crisis

Malta Water Association. (2015). State of Water Resources in Malta. Malta Water Association. Retrieved on 16 April 2018, from http://maltawaterassociation.org/index.php/portfolio-item/state-of-water-resources-in-malta/

Marcfoods (2018). Retrieved on 28 May 2018, from http://www.marcfoods.nl/

Mazza, P. (n.d.). Retrieved on 28 May 2018, from http://www.photomazza.com/Annona-glabra?lang=en

McGrath, M. (2007). Briny future for vulnerable Malta. *BBC World Services.* Retrieved on 19 April 2018, from https://www.timesofmalta.com/articles/view/20150506/opinion/Imminent-water-crisis.566982

Meijer, T. (2018, 18 May). Phone interview. Appendix 6.

Melillo, J. M., Richmond, T.C., and Yohe, G.W. (2014). Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Meriton-Jean, S. (2014). Boosting the agricultural sector to ensure food security – Seychelles is finalizing national agricultural investment plan. *Seychelles News Agency.* Retrieved on 1 May 2018, from http://www.seychellesnewsagency.com/articles/1159/Boosting+the+agricultural+sector+to+ensure+food+security++Seychelles+is+finalizing+national+agricultural+investment+plan

Mishra, A., & Tanna, B. (2017). Halophytes: potential resources for salt stress tolerance genes and promoters. *Frontiers in plant science*, *8*, 829.

Muchate, N. S., Nikalje, G. C., Rajurkar, N. S., Suprasanna, P., & Nikam, T. D. (2016). Physiological responses of the halophyte Sesuvium portulacastrum to salt stress and their relevance for saline soil bio-reclamation. *Flora*, *224*, 96-105.

NASA (2017). *Sea level.* Retrieved on 31 March 2018, from https://climate.nasa.gov/vital-signs/sea-level

National Assembly of Seychelles (NAS). (2017). Salinity status of coastal plateau not alarming as yet – study. Retrieved on 13 April 2018, from http://www.nation.sc/article.html?id=254791

National Assessment Report (NAR). (2010). *National Assessment Report Republic of Seychelles (2004-2009)*. Retrieved on 26 April 2018, from http://sids2014.org/content/documents/14Seychelles-MSI-NAR2010.pdf

National Oceanic and Atmospheric Administration, NOAA (n.d.). Where is all of the Earth's water? Retrieved on 20 May 2018, from https://oceanservice.noaa.gov/facts/wherewater.html

Netherlands Water Partnership (2018). Retrieved on 14 May 2018, from https://www.dutchwatersector.com/news-events/news/29790-salt-farm-texel-introduces-zero-water-vegetables-in-drought-stricken.html

Nicholls, R. J., & Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. *Science*, *328*(5985), 1517-1520.

No author. (2012, 9 January). Where climate change threatens survival. *The Sydney Morning Herald.* Retrieved 16 May 2018, from https://www.smh.com.au/politics/federal/where-climate-change-threatens-survival-20120108-1pq4c.html.

Norwegian Institute of Bioeconomy Research (NIBIO, 2017). Food security threatened by sea-level rise. Retrieved on 17 May 2018, from https://phys.org/news/2017-01-food-threatened-sea-level.html

Nullet, D. (n.d.). Retrieved on 28 May 2018, from https://laulima.hawaii.edu/access/content/group/2c084cc1-8f08-442b-80e8-ed89faa22c33/book/chapter_7/waterout.htm

Nurse, L.A., R.F. McLean, J. Agard, L.P. Briguglio, V. Duvat-Magnan, N. Pelesikoti, E. Tompkins, and A.Webb. (2014). *Small islands*. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy,

Panagea, I. (2017). Application of biological agents to increase crop resistance to salinity. Source found on 25-04-18: https://qcat.wocat.net/en/summary/1282/?as=html

Op Terschelling (n.d.). *Werelderfgoed Wadden Terschelling*. Retrieved on 1 May 2018, from https://op-terschelling.nl/overzicht/werelderfgoed-waddenzee-terschelling

OzCoasts (2018), Australian government, Retrieved on 4 june 2018, from http://www.ozcoasts.gov.au/indicators/saline_intrusion.jsp

Panagea, I. (2018, 24 April). Phone interview. Appendix 18.

Provincie Fryslân (n.d.). *Iepen Mienskipsfûns*. Retrieved on 14 May 2018, from https://www.fryslan.frl/beleidsthemas/iepen-mienskipsfuns_41489/

Recare. (2016). Case Study: Timpaki, Crete. Retrieved on 25 April 2018, https://www.recare-hub.eu/case-studies/timbaki

Recare Project Information Hub (2018). Retrieved on 28 May 2018, from https://www.recare-hub.eu/tools-and-outputs/recare-experiments/soil-salinization

Rengasamy, P., & Olsson, K. A. (1991). Sodicity and soil structure. *Soil Research*, *29*(6), 935-952.

Rijksoverheid (2017). *Doorbraak in voedselzekerheid met Nederlandse kennis over zilte landbouw.* Retrieved on 1 April 2018, from https://www.rijksoverheid.nl/actueel/nieuws/2017/02/22/doorbraak-in-voedselzekerheid-met-nederlandse-kennis-over-zilte-landbouw

Roep, D. (2018, 30 April). Personal interview. Appendix 14.

SaltFarm Foundation (2017, June 22). Breakthrough in food security with Dutch knowledge of Saline Agriculture. Retrieved on 18 May 2018, from https://saltfarmfoundation.com/external-news/breakthrough-in-food-security-with-dutch-knowledge-of-saline-agriculture/

Salt Farm Texel (2017). Retrieved on 31 March 2018, from http://www.saltfarmtexel.com/salt-farm-texel

Salt Farm Texel (n.d.). Retrieved on 1 April 2018, from http://www.saltfarmtexel.com/projects/salt-tolerant-potato-to-feed-the-world

Satter, W. (2018, 7 May). Phone interview. Appendix 7.

Schreijer M., Komen S.J., Poort M., Vingerhoed E., Ney N., (2012). Een Deltavisie voor Hollands Noorderkwartier; Noord-Holland voorbereid op klimaatverandering, Hoogheemraadschap Hollands Noorderkwartier.

Schulting, B. (2018, 17 May). Phone interview. Appendix 19.

Scicluna, M. (2015). Imminent water crisis. *Times of Malta*. Retrieved on 19 April 2018, from https://www.timesofmalta.com/articles/view/20150506/opinion/Imminent-water-crisis.566982

Seychelles Agricultural Agency (SAA). (2018). Mission. *Ministry of Agriculture and Fisheries.* Retrieved on 1 May 2018, from http://www.mofa.gov.sc/agency-saa.html.

Seychelles Tourism Board Pinterest (n.d.). Retrieved on 28 May 2018, from https://nl.pinterest.com/pin/ 275634439669234869/

Sharpley. R & Sharpley. J. (1997). Rural Tourism: An Introduction. Chichester: International Thomson Business. P 84.

Siegel, S. M., Siegel, B. Z., Massey, J., Lahne, P., & Chen, J. (1980). Growth of corn in saline waters. Physiologia plantarum, 50(1), 71-73.

Skerrett, A., & Disley, T. (2016). *Birds of Seychelles*. Bloomsbury Publishing.

SoortenBank.nl (n.d.). Dieren, planten en paddenstoelen in Nederland. Retrieved on 18 May 2018, from http://www.soortenbank.nl/index.php

SPA (Seychelles Planning Authority). (2018). Seychelles Strategic and Land Use Plan 2040. Retrieved on 8 May 2018, from http://www.spa.gov.sc/planning-system/plans-policies/seychelles-strategic-and-land-use-plan-2040.

Spiteri, D., Scerri, C., & Valdramidis, V. (2015). The current situation for the water sources in the Maltese Islands. *Health Sciences*, 22-26.

Stichting Texels Museum (2018). Retrieved on 28 May 2018, from https://www.ecomare.nl/verdiep/leesvoer/planten/kwelderplanten/zeekraal/

Storlazzi, C. D., Gingerich, S. B., van Dongeren, A., Cheriton, O. M., Swarzenski, P. W., Quataert, E., ... & McCall, R. (2018). Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding. *Science advances*, *4*(4), eaap9741

Stuyt, L.C.P.M., Blom-Zandstra, M., & Kselik, R.A.L. (2016). *Inventarisatie en analyse zouttolerantie van landbouwgewassen op basis van bestaande gegevens*. Wageningen, Wageningen Environmental Research, Report 2739.

Stuyt, L.C.P.M. (2018, 24 April). Personal interview. Appendix 15.

Talla, P. (2017, February 16th). FAO discusses Seychelles' potential in agriculture. *The Economist*. Retrieved on 23 May 2018, from http://country.eiu.com/article.aspx?articleid=275113611&Country=Seychelles&topic=Economy&subtopic=Forecast&subsubtopic=Economic+growth&u=1&pid=356516619&oid=356516619&uid=1.

The Union of Concerned Scientists (2016). retrieved on 28 May 2018, from https://www.ucsusa.org/global-warming/science-and-impacts/impacts/sea-level-rise-flooding-us-military-bases#.WwvxT0iFOM8

The World Bank (2018). Agriculture, value added. Retrieved on 16 May 2018, from https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=MV.

Times of Malta (2009). Malta Today Retrieved on 16 April 2018, from https://www.maltatoday.com.mt/news/national/82133/maltese_farmers_fear_farming_could_become_a_hobby#.WtShI9NuZn6

Times of Malta (2009, September 7). Gozo winery becomes attraction. *Times of Malta.*

Times of Malta (2018, April 3). Second-class water to be available for 400 hectares of land. *Times of Malta.*

TODAY. (2015). *What's salt got to do with it.* TODAY in Seychelles. Retrieved on 13 April 2018, from https://www.facebook.com/todayinsey/posts/856907804347031

Tompkins, E. L., Nicholson-Cole, S. A., Boyd, E., Hurlston, L. A., Brooks, H., Clarke, J., ... & Varlack, L. (2005). Surviving climate change in small islands. A guidebook.

United Nations (2017). World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. New York. Retrieved on 31 March 2018, from https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

United Nations Development Programme (2013). State Action Plan on Climate Change, Andaman and Nicobar Islands.

United Nations Development Programme (2016). Programme on climate change adaptation and mitigation in comesa-eac-sadc region.

UNESCO (2009). *Wadden Sea World Heritage.* Retrieved on 14 May 2018, from https://www.waddensea-worldheritage.org/wadden-sea-world-heritage

University of Lincoln (2017, June 20). Could 'saline agriculture' be the future of coastal farming? Retrieved on 18 May 2018, from https://phys.org/news/2017-06-saline-agriculture-future-coastal-farming.html

Van den Berg, M. (2017). Passive Design Strategies: For a public in the dune landscape of Texel, The Netherlands, TU Delft, Master Thesis.

Van der Plaats, D. (2018, 17 May). Phone interview. Appendix 21.

Van der Wielen, H.K. (2018, 25 April). Phone interview. Appendix 3.

Van der Zee, S.E.A.T.M. (2018, 30 April). Personal interview, Appendix 16.

Van Putte, M. (2018, 3 May). Phone interview. Appendix 11.

Van Wesemael, J. (2018, 1 May). Phone interview. Appendix 13.

Vella, M. (2017). Maltese farmers fear farming could become a hobby. Malta Today. Retrieved on 16 April 2018, from https://www.maltatoday.com.mt/news/national/82133/maltese_farmers_fear_farming_could_become_a_hobby#.WtShI9NuZn6

Vlielander Bunkerkaas (2018). Retrieved on 23 May 2018, from http://www.zeewierkaas.nl/

Velmurugan, A., Roy, S. D., Dagar, J. C., Swarnam, T. P., & Jaisankar, I. (2016). Innovative Technologies to Sustain Saline Island Agriculture in the Scenario of Climate Change: A Case Study from Andaman Islands, India. In *Innovative Saline Agriculture* (pp. 387-417). Springer, New Delhi.

Velstra, J en Voorde, M ter (eds.) (2009). Overzicht huidige kennis omtrent interne verzilting in Nederland. Acacia Water en Stowa. STOWA-uitgave 2009-45.

Waddenacademie (2015). Advies zilte teelten. Downloaded on 31 March 2018, from https://www.waddenacademie.nl/fileadmin/inhoud/pdf/04-bibliotheek/advies_zilte_teelten_maart_2015.pdf

Wetterskip Fryslân (n.d.). *Wij zijn Wetterskip Fryslân*. Retrieved on 30 April 2018, from https://www.wetterskipfryslan.nl/organisatie/over-wetterskip

White, I., 1996. Preliminary Report: Freshwater Lens Recharge at Bonriki, Kiribati. IHP-V Technical Documents in Hydrology No. 5. Paris, UNESCO: 1–38.

White, I., Falkland, T., Perez, P., Dray, A., Metutera, T., Metai, E., & Overmars, M. (2007). Challenges in freshwater management in low coral atolls. *Journal of Cleaner Production*, *15*(16), 1522-1528.

Wikipedia (n.d.). Used for translations between halophytes. All of them retrieved on 18 May 2018, from wikipedia.nl

Wolf B.T., Smith C., Sales D.I., (1980). Growth and carcass composition in the crossbred progeny of six terminal sire breeds of sheep, British society of animal production, Volume 31, Issue 3, pp.307:313

World Bank (2016). Agriculture, value added. Retrieved on 17 May 2018, from: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

World Population Review (WPR). (2018). Seychelles Population. Retrieved on 1 May 2018, from http://worldpopulationreview.com/countries/seychelles-population/

WTTC (World Travel & Tourism Council) (2017). Travel & Tourism – Economic impact 2017 Malta. Retrieved on 17 May 2018, from https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2017/malta2017.pdf

Yeo, A. (1998). Predicting the interaction between the effects of salinity and climate change on crop plants. *Scientia Horticulturae*, *78*(1-4), 159-174.

Zubari, W. K., Madany, I. M., Al-Junaid, S. S., & Al-Manaii, S. (1994). Trends in the quality of groundwater in Bahrain with respect to salinity, 1941–1992. *Environment international*, *20*(6), 739-746.

Zubari W. K., Madany I.M., Sabah S. (1994). Trends in the quality of groundwater in Bahrain with respect to salinity, 1941-1992, AI-Junaid Desert and Arid Zones Sciences Program, Arabian Gulf University, Manarna, Bahrain Environment Inteanadonal, VoL 20, No. 6, pp.742

Zuurman, W. (2018, 17 May). Phone interview. Appendix 20.

Zwart, B. (2012). Verzilting vereist zouttolerante gewassen. *Geografie.* Retrieved on 17 May 2018, from https://geografie.nl/sites/geografie.nl/files/Zwart%20-%20Verzilting%20vereist%20zouttolerante%20gewassen.pdf

9. Appendix

9.1 Interviews

1. Interview with Maartje Duin, Hoogheemraadschap Noorderkwartier (2018-05-03)

Because the island of Texel does not have a big freshwater supply, people on Texel have thought already more deeply about drought problems and salinity problems. Texel can be an example for the rest of the Netherlands. It is not allowed to abstract ground and surface water from the water system: it is not allowed for farmers to irrigate on Texel. It is therefore for Texel not interesting to be able to irrigate with more brackish water during dry conditions, because this is simply not allowed. The water board is not going to solve the water problems due to climate change, However the water board will try to maintain the current situation and no big changes will be made.

If farmers want to have more saline water for their agriculture, the water board is not going to facilitate this. It is thus only interesting for saline farmers to choose a place where there is already sufficient saline water available. Furthermore, Salt Farm Texel is also not facilitated with saline water. The Salt Farm Texel is based in the Prins Hendrik Polder, where there is a salt water source from under the dunes. However, Salt Farm Texel is allowed to abstract surface water from the water system. Lastly, the water board might be able to allow and support on small project level the use of more brackish water for agriculture, if the surrounding area is not affected by it.

2. Interview with Nienke Hamstra, Wetterskip Fryslân (2018-05-09)

It is difficult to say whether salinization will become a bigger problem for Terschelling in the future. Salinization has been a problem for a long time, but currently the situation does not really become worse. It is expected that especially the intrusion of saltwater via sea level rise will become a problem. This will cause further salinization in the lower areas of the island. At this moment there are more problems with salt water in the winter than in the summer, because in the summer the freshwater is retained. Whereas in winter there is more salt water intrusion into the ditches, which gives more salt water problems. Currently farmers are not allowed to irrigate, so irrigation with brackish water will not be an option for Terschelling. The only water source for the island is rain water that feeds the fresh groundwater lens, thus this is also the only source of freshwater for farmers as well.

The lowest areas of the island are the best for saline agriculture, especially near the water outlets. Performing agriculture here reduces the risks for the salinization of the surrounding areas. On top of that, if there are ditches between the different land parcels, the risk of salinization of neighbouring land parcels due to saline agriculture is also reduced. As long as saline farmers do not dump their saline water into the ditches, it is not the responsibility of the water board, but of the province, because then the soil becomes more saline. There is no legislation from the water board that prohibits saline agriculture. Farmers are able to pump up water, if it is below a certain amount. Lastly, the water board serves the demanders, if the whole island wants to have saline agriculture, the water board has to supply this if possible.

3. Interview with Hendrik Klaas van der Wielen, Alderman Terschelling for agriculture, nature and sustainability (2018-04-19)

There is hardly any crop production on Terschelling, farmers practice mainly animal husbandry. Saline crop production is practiced only on very small-scale and is fully focused on tourism (like cutting gardens and restaurants). Tourism is the most important sector regarding economy on Terschelling.

Opportunities for expansion of saline agriculture are limited, because the soils on the long shaped island of Terschelling contain hardly any salt water as a consequence of the freshwater flow from the dunes. On top of that, it is expected that the coming 10/15 years the salinity on Terschelling will not increase, because there is more than enough upwelling of freshwater. The only opportunities on

Terschelling for saline agriculture are in the areas outside the dykes. Furthermore, nature areas should not change into saline agricultural areas, because tourists come for the nature on Terschelling and not for the agriculture. Furthermore the animal husbandry sector does not want to have brackish water near their animals and this is the most important agricultural sector on the island.

There are a few brackish salt-marshes, which entrepreneurs use for tourism by making an tourist attraction of the small farm fields near the salt-marshes. Saline agriculture on Terschelling is only interesting if you link it with the tourism branch. This is because tourism is a constant yearly round branch on Terschelling and is 80% of the GDP. Furthermore, saline agriculture on a small-scale will be tolerated by the municipality, whereas permission for large-scale saline agriculture will be difficult.

All in all, saline agriculture is not really interesting on a large-scale on Terschelling, because the salinity does not really increase, there agricultural sector is really small and the municipality will not allow it. However, on a small-scale saline agriculture is potentially interesting with the possibility of attracting tourists with picking gardens and special local products.

4. Interview with Pieter de Vries, Alderman Texel for sustainable development (2018-04-19)
The agricultural sector is an important sector on Texel. Especially seed potatoes are really important (15% of GDP) and are exported all over the world. At this moment it is not really a problem to provide the agricultural sector on Texel with freshwater. However, for the Waldenberg Polder there is often not enough freshwater anymore at the end of the summer. This polder was first always used for the agriculture, but is now a nature area. Another polder, The Hendrik Polder, has also quite salty ditches. However the conventional farmers overt here, have systems with which they can still use the thin freshwater lens. In essence, farmers do not want to switch to saline agriculture because there is simply no need for it; they earn more than enough money with their current crops. Furthermore, the LTO is really suspicious about saline agriculture and are not supporting the idea. They are lobbying for more freshwater instead. In the far future there is potential for saline agriculture, but currently there is no need and willingness for it. Agriculture works simply better on freshwater; thus the first priority is to store as much freshwater as possible in the area.

If a farmer wants to start with saline agriculture, no extra permission from the municipality is needed if the original destination of the area is agriculture. Especially the areas outside the dykes are interesting for saline agriculture. However, the water board might not tolerate it and the neighbouring farmers will not be happy either, so it will be hard. Furthermore, Salt Farm Texel gets a lot of subsidy from the Waddenfonds and farmers in the surrounding are not really happy with that, because why do they not get anything?

Tourists come to Texel for the nature and the coast, thus it is not expected that tourists will come for saline agriculture or special products. A lot of things strengthen the identity of Texel, so one special saline product will not really change that. Furthermore, there are currently groups of people visiting the Salt Farm Texel, but these are often people from companies, students or other people that are linked to businesses. It is thus not really interesting for tourists.

Lastly, saline agriculture will not make Texel more self-sufficient, because it will only happen on small-scale and in areas where there was conventional agriculture in the beginning. However, saline agriculture could support a more circular economy. Thus, saline agriculture has potential if it complements the conventional agriculture where needed.

5. Interview with Yvonne de Vroede, VVV Texel (2018-04-12)
Local island inhabitants do not see saline agricultural products as a daily product, but more as a luxury for restaurants. Sometimes tourists visit Salt Farm Texel, but they do not really come for the saline products, they are just looking for an activity. There are barely tourists that come to the VVV and ask for saline related activities. The VVV does not work together with Salt Farm Texel. However, there is a special regional product route on Texel and saline products could be added to this route in order to show the tourists the products. More and more tourists know about the saline products and restaurants that have dishes with these products. If saline agriculture gets more attention there is potential for the combination of tourists and saline products.

6. Interview with Tineke Meijer, VVV Terschelling (2018-05-18)
The tourists that come to Terschelling are really diverse: from young to old and from couples to families, although the biggest group is between 33 and 65 years old. The VVV promotes activities from other parties. VVV Terschelling also promotes the foundation 'de Zilte Smaak' of Flang Cupido. Tourists never ask for saline agricultural related activities and tourists do not really come especially for the agricultural initiatives on Terschelling. The tourists come to Terschelling for the peace, the nature and the regional products such as the cranberry or some wines. However, they sometimes ask when and where the natural halophytes of Terschelling can be picked in the natural areas. For the future it would be interesting to organise educational tours for tourists and students in order to learn them more about saline products in collaboration with saline agricultural initiators, nature organisations and Wadden organisations. For special regional products Terschelling has the hallmark "Waddengoud". Thus, if there would be a special local saline agricultural product, it could get this mark. On top of that, saline agricultural farmers could promote their company during the 'farming days' for tourists for example. A final statement is that the VVV sees potential in saline agriculture if this could lead to nature related activities that pay attention to the unique wadden heritage and this could attract a whole new group of tourists.

7. Interview with Wessel Satter, Provincie Friesland/ Waddenfonds (2018-05-07)
This information is given on behalf of the 'Waddenfonds', because that organisation subsidizes saline agricultural projects. The provinces subsidize something, but that are really low amounts of money. For example, Salt Farm Texel is only subsidized for 3.3% by the Province which is neglectable. The Waddenfonds subsidizes this kind of projects with a significant higher amount of money. However, the Waddenfonds is not going to subsidize every saline farmer. There are a lot of subsidy-requirements for the products. They should be new and innovative for example. Furthermore, a project should gain new knowledge. The Waddenfonds is not actively searching for projects and helping people with ideas, but waits for subsidy requests. If there are no subsidy requests for saline agriculture, then they will not finance it. The vision of the Waddenfonds is that people work with water and not against it. Thus if certain areas are more suitable for saline agriculture and there are people that want to start innovative projects over there, the Waddenfonds might subsidize it.

8. Interview with Arjen de Vos, Salt Farm Texel (2018-04-17)
The advantage of Salt Farm Texel over other test locations for saline agriculture is that the Salt Farm provides more user friendly information for farmers. It is the only location with test fields outside and it makes only short reports of successes instead of long and complicated papers. To make money out of saline agriculture it is important to look at the demand. Norfolk samphire grows for example only during the spring/summer months and then there is barely demand. It is therefore more interesting to cultivate potatoes or beet, because the demand for these crops is more constant. In the Netherlands it is really important that you sell your product as a regional product with a nice and special story in order to get a higher price. Especially really expensive restaurants are currently

interested in the saline products. This is in not the case countries as Bangladesh for example, because people are poorer over there. Furthermore, the Jumbo on Texel sells special saline potatoes. They are more expensive, but have a nice story on the packaging. Other supermarkets are only interested in the product if it is as cheap as regular products.

During Thursdays in the summer months every there are big tours for tourists on the Salt Farm. There is potential to expand this, but the research would suffer from that. The tourist industry is really important for Texel and the identity can be strengthened by regional products. Almost every farmer on Texel has its own special product. However, the island identity on Texel is already really strong and determined by a lot of factors, thus one extra regional product will not make an enormous difference.

At this moment saline agriculture is interesting in the buffer zone between the coast lines and the conventional agricultural areas. This can be in balance with the nature, because you adjust your crops to the soil type and salinity level. However, saline agriculture should be more in balance with conventional agriculture. At this moment the LTO organisation that speaks for the freshwater farmers is afraid that water board will stop with flushing the more saline areas if it turns out that saline agriculture is viable as well. Water boards are more and more admitting that the flushing of saline areas is not a situation that can be maintained for ever, thus something should happen. A radical change will only happen when the necessity is there though.

Several projects are currently going on with tomatoes, lettuce, and strawberries. Strawberries were unsuccessful, but tomatoes and lettuce gave promising results. For the potatoes, a Wageningen taste panel tested the tomatoes and it turned out that they were more tasty and sweet than normal potatoes. This is due to the reason that some vegetables produce even more sugars in salty circumstances, as a biological reaction to counterbalance increasing salt content in the soil. Especially during the germination phase, plants need more freshwater and after that phase they can handle higher salt concentrations.

Thus, saline agriculture has a lot of potential, because in the future there will become a need for it and there is currently already a lot of demand from foreign countries.

9. Interview with Flang Cupido and Hans Wilmink, Flang in de Pan (2018-04-24)

This year a project regarding saline agriculture has started. The initiative started from an environmental point of view. Why do the shops have Norfolk Samphire from Israel or Mexico, whereas it is possible to produce it in your backyard. There is enough demand in the periods that Norfolk Samphire can be produced on Terschelling due to all the tourists that come to Terschelling. Most halophytes that are used, grow exactly during the tourist season, thus that works perfectly. Furthermore, it is not really a luxury product, because you can do a lot of things with the halophytes.

There is potential on the market on Terschelling, because Flang in de Pan is currently the only entrepreneur in this sector and there is more than enough demand. More initiatives could ruin the market though. At this moment, Norfolk Samphire, sea aster, rock Samphire, sea plantain, ice plant and chard are being produced on small fields next to each other. This is the first production year, so time has to learn whether it is going to be a success. However, they grow all around Terschelling, thus they will grow on the made fields as well. On Terschelling the circumstances are harder to control than on Texel. In April the soil is not saline enough, but if it gets drier, the soil will become more saline as well. The expectation is that especially that Ice plant and Norfolk Samphire are going to be best sellers, because those plants have a story that makes it easier to sell.

Especially the areas outside the dykes are interesting for saline agriculture, because they cannot be used for conventional agriculture. For that reason, conventional farmers are not suspicious and are fine with the developments. The plan is to establish a picking garden for tourists in such an area. In this way you can combine biodiversity on the island with a tourist activity and you use an area that is not suitable for conventional agriculture. For tourists it is not interesting to adjust conventional crops in a way that they can cope with more saline conditions, because they want to have special products with a story.

For Terschelling saline agriculture has potential for the tourists. In the end, the aim is to connect the saline products with the island identity and to strengthen the identity.

10. Interview with Nils Koster, Vlielander Bunkerkaas (2018-05-07)

Special cheese is made in Vlieland, in which seaweed is used. Cheese making is a passion and because it is nice to use something from the island in order to make it a real 'Vlieland' product, seaweed is included in the cheese. The seaweed comes from wild seaweed around the island, but currently there are also tests with test facilities in order to cultivate seaweed. This in order to guarantee a higher quality and to be able to regulate everything.

Vlielander Bunkerkaas is the only company that produces seaweed cheese, thus there are restaurants and demanders all over the world interested in his products. However, it should really be your passion to make such a product because it costs a lots of work and is very expensive. However, because this is unique, a high price can be maintained and it is still interesting to make this cheese. Vlielander Bunkerkaas is a member of "Stichting Noordzeeboerderij", which is an organisation that connects seaweed demanders and suppliers. However, the saline agriculture is really in its beginning stages. An ecologist investigated the effect of seaweed cultivation on the ecology of the island of Vlieland. According to this ecologist and another professor there where only positive influences, because the cultivation location becomes a breeding ground for many sea animals. Unfortunately, there is no support from the local city council, because the needed permits are not given. A city council should support new initiatives in order to enhance the creativity. Also, it is believed that the small size of Vlieland really helps in promoting a new local product.

11. Interview with Maja van Putte, ZLTO (2018-05-03)

This year there has been a survey under farmers from Zeeland about the potential of saline agriculture. However, there were only twelve farmers that responded. 33% of the respondents said that their farm is located in an area with salinity issues and 66% said that they are interested in crops that are more salt tolerant. This information is interesting for the future, because farmers said that it is harder and harder to get freshwater at the right moments. The reason that some farmers are not interested in saline agriculture, is that they simply have no salinity problems or are happy with their current crops.

Furthermore, it turned out that 75% of the farmers know about saline agriculture, but almost nobody knows how to cultivate them. However, 66% of the farmers is interested in it. Farmers are interested because some hope that the prices of saline crops are fluctuating less than the prices of conventional crops, some want to expand their farm towards more saline soils and some are worried about the future.

However, the ZLTO notices that there is still a big group of farmers very suspicious towards saline agriculture, simply because they are afraid that their agricultural areas will become more saline if a neighbour has saline agriculture. Furthermore, currently the focus lies on the storage of freshwater and keeping the saline water far away.

In the opinion of the ZLTO, the change of further salinization due to saline agriculture and the thread to neighbouring farmers should be investigated more in order to be able to advice farmers properly about it. The ZLTO wants to support farmers who dare to be creative and have new ideas, but at this moment, farmers really see saline agriculture as the last possible adaptation method, which should only be used if nothing else is possible.

12. Interview with Hubrecht Janse, Zeeuws Zilt (2018-05-01)
Because there were plans to increase the salinity in the Veerse Meer, there was a threat that the agricultural fields would become more saline. Besides that, it was interesting to try a new crop. Then there was decided to experiment with Norfolk Samphire on a small piece of land. However, the conventional agriculture is still the most important for the company. It is possible to have saline agriculture next to conventional agriculture, because the saline agricultural area is located on the lowest land parcel. This is also why the water board allows it, because it is the lowest land parcel and no other parcels are affected.

Cultivating saline crops takes more time, because it is a lot of handwork and actively irrigating with salt water. Furthermore, only biological pesticides are used for the saline agriculture, thus it is better for the environment as compared to conventional agriculture on this perspective.

Saline agriculture is not the foundation of the company. The market is too small for it. However, there is potential for saline agriculture if the demand is high enough on the right times. It is hard to compete with big trading companies from abroad. At this moment the farm sells cosmetic as well as food products directly to other small shops in the neighbourhood and via the farm shop. However, it is really important that people are made aware of the fact that these saline products are seasonal products. Thus if people want to have Norfolk Samphire during Christmas it is from abroad and not a local product. Saline agriculture should really be an voluntary choice from a farmer, because you should be really interested in it in order to make it a success.

13. Interview with Jean-Pierre van Wesemael, Saeftinghe Zilt (2018-05-01)
Because the farm is located close to a dyke there is salt water available and because there was an idea to broaden the crop spectrum it was chosen ten years ago to experiment on two hectares with the salt tolerant crops Norfolk Samphire and sea lavender. Now, more hectares are added with sea kale. The used parcels are lower and have ditches around it, so there is no danger for the other parcels. At first, the products were sold directly via the farm to people or restaurants. The farm is currently also working with trading companies. Saline agriculture is a special niche and if you couple it with a nice story and cultivate it on a larger scale, you can have economic benefit from it. To have economic benefit from it, it is also important that the price per kilogram stays high. To get this high price, the supply should stay low, so cultivating halophytes on a large-scale is not a smart option. This high price for the product is needed because cultivating these vegetables is a lot of handwork and thus really expensive. The real potential for saline agriculture lies in making conventional crops more salt tolerant such as the saline potato, because there is a year round high demand for these products.

14. Interview with Dirk Roep, WUR Department of Social Sciences (2018-04-30)
The switch to saline agriculture is still in the experimental phase. On the Wadden Islands there is little cultivation of crops for commercial purposes. Vegetable crops have relatively low margins of profit, so farmers will not switch that easily to saline vegetable crops. Therefore, it is necessary to give products an added value. For example, one could sell it to (local) restaurants.

Furthermore, it is important to look from a farmer's point of view when trying to make saline agriculture successful. A farmer will be easier convinced to do saline agriculture when the switch starts with an existing concept that will be aggrandized to a commercial concept related to saline agriculture. In general, most of the farmers are not very interested in change. When the farm produces well, farmers are not going to switch to saline agriculture. It is important to focus on farmers or other people that see saline agriculture as a solution for themselves.

Besides that, it is important to search for the right people to set up a business for saline agriculture. A pioneer or hobbyist that is willing to invest a lot of time and effort in an innovative project. Either people that are willing to develop their hobby commercially, or people that are forced to search for other opportunities. Mostly, people that start an initiative are forced to be innovative and search for another market, because they do not fit in the existent supply chains. The people starting saline agriculture need to have the right competences. Besides having knowledge about farming, they must be good networkers and be able to come up with a nice background story about their products.

The conclusion is that saline agriculture is interesting to do. Start small and find out what you want to achieve. On this basis, start to create plans and search for the right people to invest. People with pioneering spirit. Start with a concept that already exists and enhance this.

15. Interview with Lodewijk Stuyt, WUR Environmental Research (2018-04-24)

Saline Agriculture has barely potential in the Netherlands because there is simply no necessity for the coming 10 years. The only necessity is there when there is a drought and a dilemma between no irrigation or irrigation with brackish water. Therefore, the only potential lies within making the conventional crops slightly more salt tolerant with the result that they can be irrigated with slightly brackish water. Another option would be small-scale fields with local halophytes and salt tolerant herbs that could be interesting for tourists. For large-scale saline culture is simply no demand. It is too expensive, the products are not popular and other farmers do not want to have saline famers next to them, because it is almost impossible to be sure that the salt water will inundate into their lands. A big company Agrico has stopped making crops more salt tolerant because they know simply not enough about the link between the roots and the shoots.

16. Interview with Sjoerd van der Zee, WUR Department of Environmental Sciences (2018-04-30)

The literature about the salinity sensitivity of plants is highly unstructured and therefore difficult to compare. On top of that, several areas have all problems with different salt types. Research in these areas is thus also not comparable. For the coming ten to fifteen years the salinity problems in the Netherlands will not become significantly worse than they are now. A complete transition within this timeframe is not viable, but it is wise to start think about this transition though. In areas where the ditches are below NAP or where the soil is more clayish the first serious salinity problems will develop. If the soil is clayish, structure problems will develop due to high salinity levels in the soil. Most islands have a fresh groundwater lens below the surface that represses the salt water. The major thread for these systems are droughts. Water withdrawal makes the fresh groundwater lens thinner and this gives the opportunity for saline water to well upwards. It is difficult to have saline agriculture next to conventional agriculture, because it is impossible to keep the saline water separated from the freshwater. Large buffer zones are needed then. Taking everything into consideration, saline agriculture has potential on the long run for areas that are so saline that they can only be used for saline agriculture and for nothing else. Richer farmers will just create agricultural field which are not

saline. Another idea might be to replace marginal crops (crops that have a low financial profit like most vegetables) by crops that have a higher financial profit such as flowers. In other words, if you are able to adapt financially interesting crops to higher salinity levels, you might be able to replace to marginal crops and make a higher profit out of it.

17. Interview with Joseph Buhagiar, University of Malta Department of Biology, Faculty of Science and Director of Argotti Botanic Gardens (2018-05-16)

In Malta there are salinity problems for several reasons. Some land is below sea level; thus sea water can infiltrate into the sewage system. Sometimes the sea level is up to 30 centimetres higher than the land water level and that is already enough for saltwater intrusion. Furthermore, some hotels use reverse osmosis to filter water. The leftover salty water is disposed into the sewage system. Lastly, some hotels use sea water to flush the toilet for example and also this is disposed into the sewage system afterwards. If this sewage water is treated by wastewater treatment plants, the cleaned water is still salty. Many farmers refuse to use this brackish water, because it is bad for the plants and the soil structure. For that reason, the government decided to install two new treatment plants that treated the water again in order to make it less salty. This works, but is really expensive. Another problem is the extraction of groundwater: more water is extracted than is coming in, thus there is a water shortage in the aquifer that is filled with seawater. Especially during summer, the water is more saline and farmers do have problems. It is difficult to say whether the salinity will increase due to climate change.

Farmers close to the coast have already adapted to the saline conditions. They chose crops that are more salt tolerant such as barley or they use halophytes on a small-scale. They use for example species from the Amaranth family, or Chicory or Spinosum. It would really help if there could be irrigated with more brackish water on Malta, thus it would help if farmers can use plants that are slightly more salt tolerant.

It is also a possibility to use halophytes. However, currently it is not normal for Maltese people to eat daily saline agricultural products; they are not used to it. It needs exploration and publicity. However, restaurants do have it for the tourists, thus it could be an interesting business for the tourists. Currently there are strawberry picking gardens for tourists, thus this could also be done with wild halophytes.

Another problem Malta is facing is that the young farmers see farming as a weekend job, they do not think it is trendy and nice anymore. The low number of farmers decreases the self-sufficiency of the island, because more and more products are imported. An innovative idea such as ‘trendy’ saline agriculture might motivate young farmers to choose a farming career.

Saline agriculture might be interesting for Malta, if slightly more salt tolerant crops could be used such that there can be irrigated with more brackish water. On top of that cultivating halophytes might be interesting for the tourist industry.

18. Interview with Ioanna Panagea, University of Leuven and RECARE (2018-04-24)

On Crete, the biggest salinization problems are in the Tympaki, Ierapetra, Falaserna and Palaiochora regions. The problems are caused because of overexploitation of the groundwater, due to the use of high demanding crops which are chosen because you can earn a lot of money with them. This leads to salt water intrusion and the groundwater thus becomes more saline. Because farmers still earn a lot of money with these crops, they do not want to change to other crop types or saline agriculture, but they try other ways to protect their crops such as rain water harvesting. In the area of Lerapetra there were a lot of experiments with rain water harvesting for greenhouses. The reason that they investigated this was to avoid irrigating with saline water. If you want to build a greenhouse as a farmer, it is currently obligatory to have a rainwater harvesting system installed.

19. Interview with Boy Schulting, chef at restaurant 'T Pakhuus, Texel (2018-05-17)

Restaurant 'T Pakhuus is a fish and seafood restaurant on Texel. The restaurant uses Ice plant, Norfolk Samphire, Sea Lavender and, to a lesser extent, Rock Samphire. They like to use halophytes instead of other vegetables because it is very unique. The restaurant is open for other Halophyte product, but the product availability is limited. They sometimes use Norfolk Samphire as a replacement for salt. The halophytes are mostly used as consumable decoration on the plate, it adds extra value and a story to the products. Halophytes are expensive, probably due to the absence of large-scale production. For this reason, they are not often processed in a large salad between other vegetables, they are always placed somewhere where they clearly can be seen. They once had saline produced arugula, which was tastier than normal arugula and a big success, but it is out of the stores. People tend to ask what the halophyte products are, they mostly do not know them yet. The restaurant likes most to use local products because it adds to the story, but off season this is not always possible.

20. Interview with Werner Zuurman, chef at star-awarded fish restaurant 'Caracol', Terschelling (2018-05-17)

Restaurant Caracol is a star-awarded fish restaurant on Terschelling with a Wadden speciality. The business is 25 years old and has its own typical method to obtain the products that are used in the restaurant. Namely, the island's own local products for the dishes that are served in the form of decoration are used. For this, volunteers are asked to pick some of the crops whenever they go for a walk. Also, the restaurant has its own garden from which halophytes such as Norfolk Samphire are being picked. It is emphasized that picking your own products is way cheaper than importing them from other areas; it would also be an unnecessary thing to do since these products grow locally.

The main reason for using local products instead of other foreign products is that this introduces these to the public. In this way people which are not familiar yet with halophytes and other local plants learn about those plants. It is expected that over time something like Norfolk Samphire will become very normal to customers, just as the case of olives, which were not that familiar to the public some decades ago, but are now commonly accepted.

Caracol is experimenting a lot with saline products. For instance, they made a sauce consisting of seaweed and also mayonnaise out of algae. In this way, the restaurant is trying to put products related to halophytes and the island itself on the map, thereby promoting the identity of Terschelling.

21. Interview with Dewi van der Plaats, chef at restaurant 'Vincent Eilandkeuken', Texel (2018-05-17)

At restaurant 'Vincent Eilandkeuken' many local products that grow on the island of Texel itself are used. Norfolk Samphire, Ice Plant, and oysterleaf are a few examples of them. The reason to include halophytes in the dishes that are served is primarily because of the salty taste and not so much for decoration of the plates. There is also a collaboration with Marc van Rijsselberghe, who is a grower of saline potatoes and other vegetables on the same island. Van Rijsselberghe provides Vincent Eilandkeuken with a diverse of set of saline herbs, amongst others.

The use of local products is a strong part of the philosophy of the restaurant. Local products are being integrated in the restaurant's methods as much as possible due to their incredible saline taste. For this reason, not only tourists, but also many local inhabitants are coming back to have a nice dinner. Also, many customers are interested in the story that is behind the products. The menu does change a lot over the year, because of the seasonal character of the products. What ingredients are on the menu is strongly dependent on the market's supply at that particular moment. During the winter season, for example, most the products are not available because they do not grow at that time on Texel. However, the crops are not imported from countries like Israel, reflecting the restaurant's philosophy regarding the use of local products only.

In short, local products from Texel are getting more popular, both on the island itself but also in other areas of the Netherlands. Export from the island to the mainland has been increasing over the years and it is expected that the demand for Texel's products will even be higher in the future.

22. Interview with Jouke Velstra, manager and senior advisor at Acacia Water (2018-05-23)

Acacia water assesses the salinity throughout the Netherlands. Especially the lower lying parts of the Netherlands are threatened by salinization and it is expected that it will become worse in the future due to climate change. A lot of farmers do often not realize that their crops suffer from salinity damage, but they often think that the damage is caused by droughts or the wrong crop choice. In the inland of the Netherlands the high salinity levels in the lower parts are caused by a too thin freshwater lens. During dry conditions, plants transpire and the salt water will come to the surface. This means that salinity is a bigger problem during the summer months. Furthermore, land subsidence causes higher salinity levels as well. On the islands Texel and Terschelling salinization due to sea level rise is also very important. On these islands there are already locations that are really salt. Furthermore, it is expected that this salinity will increase. For Texel the Prins Hendrik Polder is already quite saline, as well as some polders more to the north.

For the coming two generations it is not a problem to have enough freshwater available. However, near areas where the soil is already too saline, saline agriculture might already be interesting. Much is not known about saline agriculture, so further research is really necessary. The problem is that on the islands the main cultivation are seed potatoes. At this moment, farmers earn a lot of money with these potatoes and there is for them no need to make the transition towards saline agriculture, that might be only interesting in twenty years. On top of that, the Netherlands have a precipitation surplus, thus the land will become less saline slowly. Therefore, for saline agriculture it is necessary to have a whole new hydrological system, in which there is a constant stream of saline water. Furthermore, large areas have clay soils and clay gets a bad structure, if it becomes too saline. On the other hand, it is already a great investment to investigate saline agriculture, because the salinity will increase and will become more and more interesting.

A lot of farmers are afraid that if their neighbour cultivates saline crops, their land will become saline as well. This is not true. The influence of one parcel on a neighbouring parcel is minimal. A lot of farmers do not understand the hydrological system, thus creating awareness among the farmers, that these kind of statements are not true is very important.

It should be possible to combine nature and agriculture with each other. It is not easy and it is not possible without a bit of creativity, but a combination between saline agriculture and nature should be possible, because saline agriculture is already a creative and innovative idea.