

Saline Prospects

An assessment of the viability of saline farming of quinoa and seed potatoes in the Netherlands

Mare Anne de Wit
2682453
Msc Environment and Resource Management
Vrije Universiteit Amsterdam
Supervisor: Prof. dr. ir. P. Vellinga and
dr. K. Negacz

JUNE 29, 2020

Preface

During the master Environment and Resource Management I touched upon multiple subjects that I would like to investigate during my thesis. They varied in theme, however, they all had one thing in common: focus on possibilities rather than problems. Since I try to live up to this motto, I wanted to bring this into practice during my final research. Therefore, it is no surprise that I immediately became enthusiastic once I read the scope of the SalFar project. In my own words; *when soil becomes too salty and/or freshwater too scarce, let's start to cultivate salt-loving cultivars.* SalFar provides tangible proof that saline farming is part of the answer on how to feed people in the future without exhausting our natural resources. This sounded exactly the optimistic type of sustainability I would like to be a part of; embedding opportunities within threats by making discarded agricultural land beneficial again, thus providing food from marginal resources and meanwhile improving biodiversity. However, as I read more and more, I became a little sceptical. If this is such a good idea, why is it not executed more often already? I started looking for the reason behind this question, thus this interest became a research project for my thesis.

This research is part of two interregional projects; SalFar (i.e. SALine FARming) and SALAD (i.e. Saline AgricuLture for ADaptation) and supported by the Waddenacademie. It has been very interesting to enter an academic process and contribute to a larger whole. Of course, I could not have done this on my own, and therefore I would like to thank my supervisor Pier Vellinga as well as Kate Negacz for their time, patience and support. I was honoured to cooperate with such inspiring researchers, and although I was aware of the somewhat negative myth that is connected to writing a thesis, thanks to them and my enthusiasm concerning the subject I did not once experience this period in a negative manner. Thus, courtesy of Pier, Kate and the support of my family and friends, I found the development of this thesis a grand adventure which I look back on with great contentment.

June 29th, 2020, Amsterdam
Mare Anne de Wit

IVM Institute for Environmental Studies VU waddenacademie Interreg North Sea Region SalFar European Regional Development Fund EUROPEAN UNION

Abstract

The process of salinization will be one of the key difficulties that the global agricultural sector will face the coming decades as it currently affects 11% of global irrigated land and is expected to worsen. Both mitigative and adaptative strategies may aid in the reclamation and management of salinized soils. As climate change leads to rapidly increasing salinization, further examination and implementation of these alternative strategies needs to be accelerated. This research focusses therefor on the examination of cultivation of salt-tolerant crop species as an adaptative measure to enhance productivity of marginal soils suffering from salinization. As the main focus previous research is on identification of strategies rather than their feasibility, this study highlights two potentially salt-tolerant crops and looks at their viability and scaling potential from an interdisciplinary and socio-economic perspective. Semi-structured interviews were conducted to identify the opportunities and constraints for the scaling of both products. Additionally, it is indicated what is currently locking-in unsustainable measures and what supports a transition to 'move with' the occurrence of salinization. Findings show that currently, salt-tolerant cultivation of quinoa and seed potatoes is not yet perceived viable due to lacking economic benefits and lacking awareness. These lock-ins can be overcome by the utilization of the emergence of windows of opportunities such as Covid-19 and recent droughts. In order to do so, policy recommendations are given. These insights are of great importance in decision-making processes of various stakeholders, ranging from farmers to governmental and political agents within or outside the agricultural field.

Keywords: salinization, climate change, saline farming, salt-tolerant cultivation, adaptation, quinoa, seed-potatoes

Tables and figures

Tables

Figures

Table of Content

1 Introduction

1.1 Salinization: a growing threat

As the second biggest exporter of agricultural products worldwide, the Netherlands is important in the global food provisioning system (Rozemeijer *et al*., 2017). However, the ongoing process of salinization is posing risks for the Dutch agricultural sector, as it threatens high yields and high-quality products that are considered necessary if the Dutch agricultural sector is to remain as profitable in the future (Dijkema *et al.,* 2005). Salinization occurs when salts, dissolved in water, accumulate in (arable) soil (Jones *et al.,* 2012). This leads to the loss of the emerging resources, goods and services of soil, resulting in land degradation and decreasing crop productivity (Daliakopolous *et al.*, 2016). The Netherlands has a centuries-old tradition of dealing with salts, as a quarter of the country is located below sea level and over 65% would potentially be flooded without the invention of dykes and polders (Huisman *et al.,* 1998). These characteristics make the Netherlands in essence already prone to salinization, however, climatic changes such as more frequent droughts and rising sea level is expected to increase the salinization problem (Oude Essink *et al*., 2010). Moreover, the availability of fresh water in the Netherlands is predicted to come under increasing pressure as supply is decreasing and demand is increasing (Stofberg *et al*., 2017).

Salinization does not only pose problems for the Dutch agricultural sector but is a global threat. The process is estimated to affect over 11% of agricultural land worldwide in over 100 countries (Ondrasek *et al.,* 2009) and is expected to exacerbate rapidly (Carillo *et al.,* 2011). The resulting land degradation poses severe problems for food production, as the population is expected to grow to 9.6 billion by 2050 (FAO, 2011), leading to a 70% rise in food demand (Nachshon, 2018). Concurrent, the global water demand will also increase. Already, fresh water is a severe concern in many parts of the world and is expected to aggravate in the coming decades (Nangia *et al.,* 2008). Salinization can thus impair food production, freshwater resources, environmental health and potentially result into a socio-economic issue (Ondrasek *et al.,* 2009) that hinders economic and generic welfare (Brevik & Sauer, 2015). The COVID-19 crisis further revealed the insecurities of the current food system and pushed focus on local food production. The main challenge therefore will be to ensure sustainable growth in agricultural production without compromising the environment and natural resources. Alternative strategies and agricultural practices that incorporate salinization can thus represent a valid help for meeting the rising food demand, preserving the already overexploited freshwater and prohibiting land from severe degradation (Atzori *et al.,* 2019).

1.2 Saline farming: a transition to adaptation

Saline farming is such a strategy, which represents a method concerning the cultivation of salt-tolerant crops using marginal, saline soil and salt-containing water (De Vos, 2016). By the utilization of marginal resources, pressure on freshwater and arable land is released and biodiversity is increased. Thus, this strategy consolidates the rehabilitation of degraded lands, CO2 sequestration and improving the resilience of communities worldwide (Dijkema *et al*., 2005). Saline farming is often mentioned as a promising method to support future food and water demand (Stuyt *et al*., 2016) with an estimated 400 million hectares of saline soil that could potentially feed up to two billion people (Wicke *et al.*, 2011).

To decide whether a crop is suitable to grow under saline circumstances their salt-tolerance is taken into account. This research focusses on two crops that have been identified as potentially salt-tolerant crops in recent research: (certain) seed potatoes varieties and quinoa (De Vos, 2016). Both important crops because of their high nutritional value and subsequently their increasing demand (Bazile *et al.,* 2016; NAO, 2020). However, the scaling potential of their salt-tolerant varieties is not sufficiently determined in previous literature as the focus currently mainly lies on identification of strategies rather than their feasibility (Van Bakel en Stuyt, 2011; Stuyt, Blom-Zandstra & Kselik, 2016). The term scaling hereby includes upscaling and outscaling and is similar to increasing as well as expanding (Wigboldus *et al.,* 2016). If the occurrence of salinization on agricultural parcels in the Netherlands were to become so pronounced that current agricultural practices are no longer possible, saline farming may pose an interesting alternative. However, its potential depends on the socio-economic perspectives that it can offer (Stuyt *et al*., 2016).

1.3 Research question

This research therefore examines the opportunities and constraints for the scaling of saline farming of quinoa and seed potatoes. With that aim in mind, the value chain of both products is utilized. The value chain involves all activities that add value to a certain product (Herr, 2007) and has not been examined for salt-tolerant cultivars before. If a weak link appears within the chain, the chain is at risk, especially in an environment where local companies compete with external businesses on both the national and export market. However, there are hardly insights regarding the value chain of, or the transition pathway to the scaling of saline farming of quinoa and salt-tolerant seed potatoes in the Netherlands to be found. This lack of knowledge appears makes it hard to identify opportunities and constraints. In order to fill the identified knowledge gap and therefore enhance decision-making processes in the agricultural as well as the political field, this research will answer the following research question:

Is the saline farming of quinoa and seed potatoes considered a viable option in the Netherlands based upon the opportunities and constraints of the scaling of both products?

The following sub-questions are incorporated to answer the research question:

1. What is the current knowledge of Dutch production of quinoa and salt-tolerant seed potatoes?
2. Which properties of the value chain affect scaling possibilities of Dutch quinoa and salt-tolerant seed potatoes?
3. Which opportunities and constraints for scaling are currently emerging within the sector?
4. What stimulates and what obstructs the transition towards cultivation of quinoa and salt-tolerant varieties when facing salinization?
5. Based on the findings of this study, what are policy recommendations that improve the scaling of both products as an adaptation measure to salinization?

Justification for this research can be found in the examination of a strategy that consolidates global food demand and water scarcity by the utilization of marginal resources. Moreover, if saline farming becomes an important adaptation strategy, the opportunity to be a frontrunner in its development and the exploitation of this knowledge can benefit the Dutch agricultural sector as well as peripheral and developed areas worldwide. Until now, research concerning saline farming mainly focusses on 'what could be possible', e.g. suitable strategies and applicable cultivars (Stuyt *et al.,* 2016). This research therefore aims to bring a novel scope into the examination of saline farming; the socio-economical perspective and interdisciplinary approach supported by utilization of the value chain. Thus, new insights in its prospects can be obtained as viability and feasibility are scrutinized. As such, this research has the potential to offer policy-makers novel information.

2 Literature review

2.1 The definition of salinization

Salinization is a subject researched in multiple fields; therefore, multiple definitions exist. In this study, salinization is defined as the accumulation of salt in (arable) soil (Jones *et al.*, 2012).

2.2 Salinization in the Netherlands

In general, within the Netherlands external and internal salinization are distinguished. External salinization occurs when salt surface water enters the freshwater system and internal salinization refers to seepage of saline groundwater (Schaap *et al.*, 2013). Because of the construction of dunes, dykes and beach ramparts the seawater became locked-out, resulting in rainwater to locate itself as freshwater lenses on top of the old salt groundwater (Stuyt, 2011). The development of 'polders' disrupted this complex system of groundwater transportation between soil layers. Originally, saline groundwater was immobile, but influenced by 'verpoldering' and reclamation it slowly began to move again, resulting in deep-lying saltwater to move upwards as seepage (see figure 1).

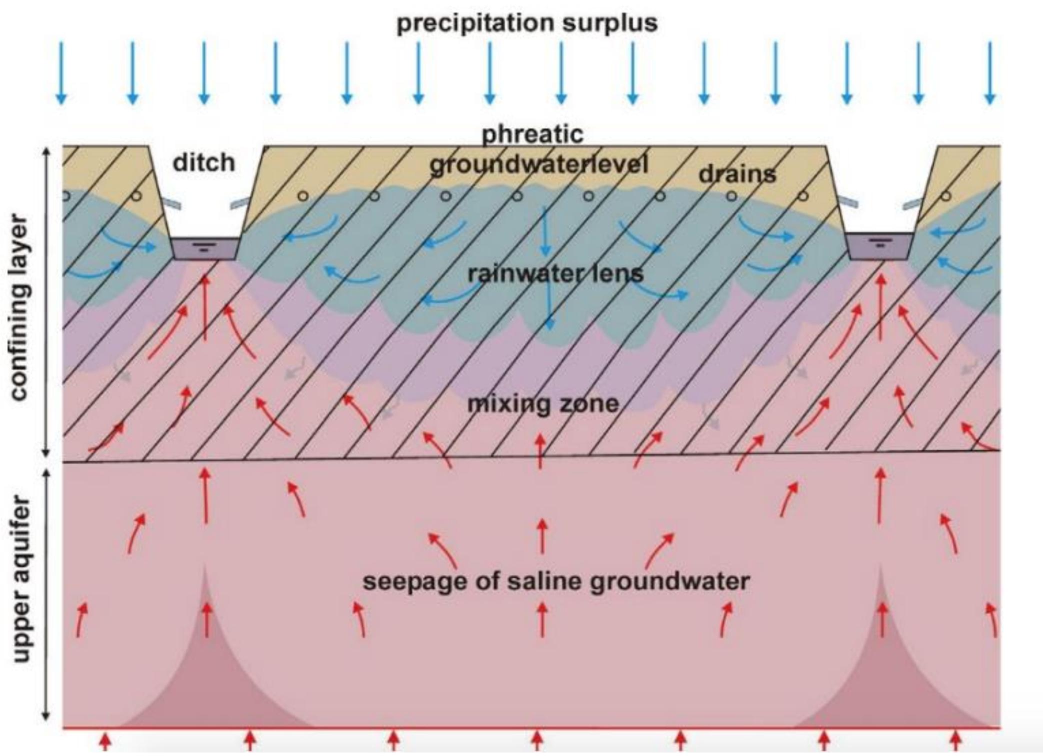

Figure 1. Conceptual visualisation of a rainwater lens on top of saline groundwater, adapted from *De Louw et al.* (2011)

The salt material migrates to the root zones and soil surface due to the natural process of evapotranspiration and capillary action. Both processes extract water out of the soil, thereby leaving solutes. This process continues until saturation is reached, after which the solutes start to precipitate (see figure 2) (Nachshon, 2018). The degree of damage to the cultivar is determined by the salinity, the growth phase in which exposure occurs and the duration of exposure. Furthermore, salinization affects the soil structure, as it decreases the permeability. Thus, more soil tillage is required to increase the ability of plant roots to penetrate the soil (Dam *et al.,* 2007).

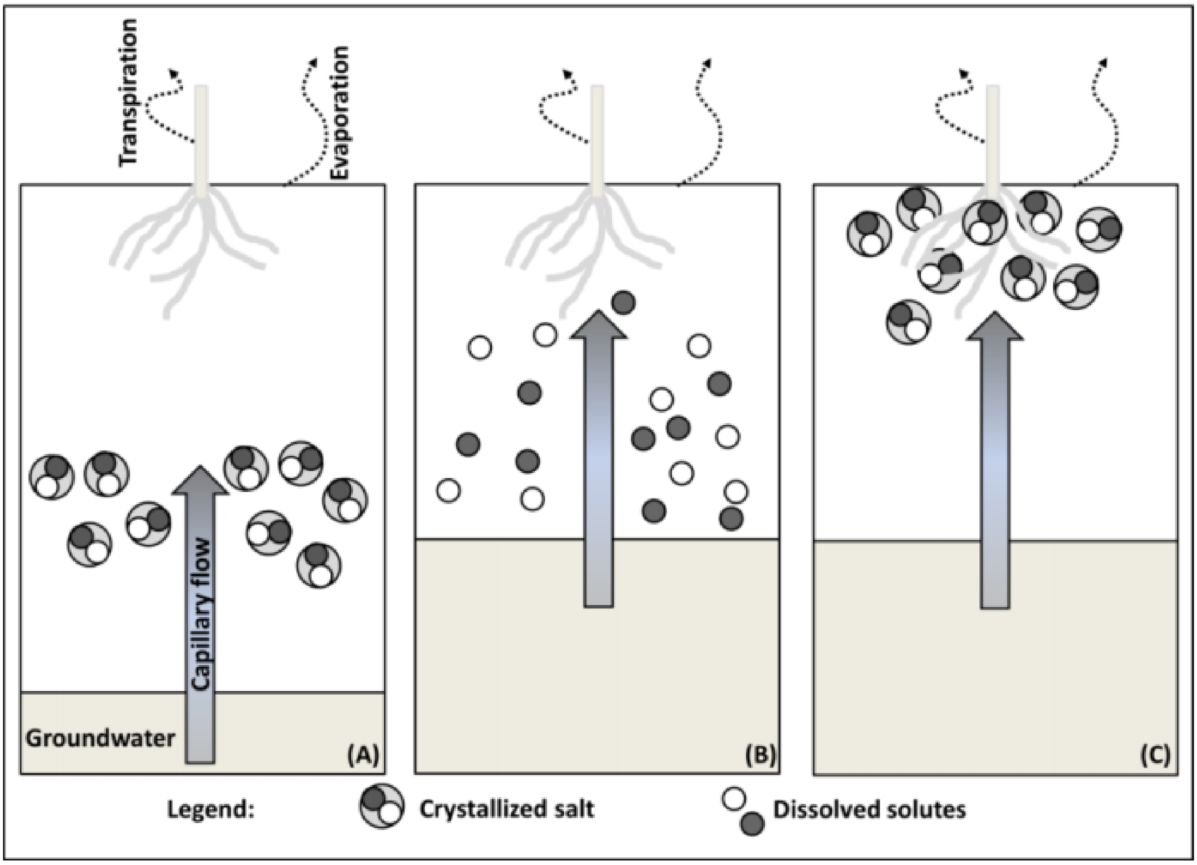

Figure 2. Soil salinization: A) salt locates at deep parts of the soil and groundwater; B) capillary action elevates the ground water, dissolves and transports the salt to the roots; C) evaporation or consumption precipitate salt in or near the surface, leading to soil salinization. Adapted from *Nachshon (2018)*

This process of internal salinization largely determines the Dutch pattern and intensity of current salinization and its future increase (Satijn & Leenen, 2009). Because of the formation of rainwater lenses the saltwater gets leached out. These lenses are also crucial as freshwater resource for agricultural production and biodiversity (Stofberg *et al.,* 2016). However, because of more frequent droughts these lenses can vanish, which occurs mostly in summer months (Stuyt *et al*., 2016). Climatic changes are expected to result in higher intensity and frequency of droughts, decreasing freshwater from rivers and rising sea-level and subsidence which all increases the intensity of seepage salinization (De Boer & Radersma, 2011; Staveren & Velstra, 2011; Schaap *et al.*, 2013).

2.3 Water management in the Netherlands

As the delta of several rivers and characterized with affluent rainfall, freshwater scarcity is not a common threat in the Netherlands. Most freshwater demand from provinces is obtained from our canals and our rivers, i.e. the main water system, with the Rhine as most important (Arnold *et al*., 2011). Since the construction of the Afsluitdijk, the Netherlands (almost always) had access to a large buffer of fresh water from the Ijsselmeer. Only the province of Zeeland and the Wadden-region lack external water supply and have limited fresh groundwater, thus are dependent on precipitation (Arnold *et al*., 2011). However, the availability of freshwater resources such as the Ijsselmeer is expected to become more limited due to climatic changes (Staveren & Velstra, 2011). Thus, the need for a shift from a freshwater dominated system to a water system that is influenced by salt-water intrusion is identified (Programma 'Naar een rijke waddenzee' (PRW), 2019). However, in general, dominant land- and water practices of waterboards and provinces that unintentional aggravate salinization still prevail (Beauchampet, 2019). In most governmental reports the different responses to salinization are distinguished in either mitigation or adaption. The first has preference and consists counteraction, e.g. artificial leaching and drainage systems, whereas the latter looks at opportunities to 'move' with the occurrence of salinization (Klein *et al.,* 2007). There are regions with a future perspective for conventional agriculture supported by mitigative measures, but there are also regions where adaptative measures are needed (Prins & Zoetendal, 2011).

The various freshwater resources made that the distribution of water is managed through demand, defined as 'water follows function' (Ter Maat *et al*., 2014). Supplementary, the Dutch water sector developed a hierarchical system defined as the 'water distribution priority sequence' in order to manage the demand for water during crises (see figure 3). In times of imminent scarcity, this determines which sector has the highest priority for freshwater supply, whereas the latter have lower priority and thus higher risks of shortages (National Water Plan

2016-2021). The low priority of agriculture in the sequence makes constant fresh water supply for agricultural purposes in dry circumstances uncertain, thus the now frequently used method of artificial leaching[1] is fragile. Looking at the increasing salinization and decreasing water supply, it may therefore be advisable to 'move with' the increasing salinization risks and cultivate crops that are less sensitive to salt (PRW, 2019). If farmers opt for more salt-tolerant crops in their cultivation plan, their yields will be less dependent on fluctuations and trends in the salinity of soil moisture and irrigation water. It will enable water managers to control the desired salt content in the surface water used within wider bandwidths and is therefore more cost-efficient. More flexible salt management is thus beneficial for the various functions that the water system fulfils for different users; e.g. agriculture, industry, drinking water and nature (Ter Maat, *et al*., 2014).

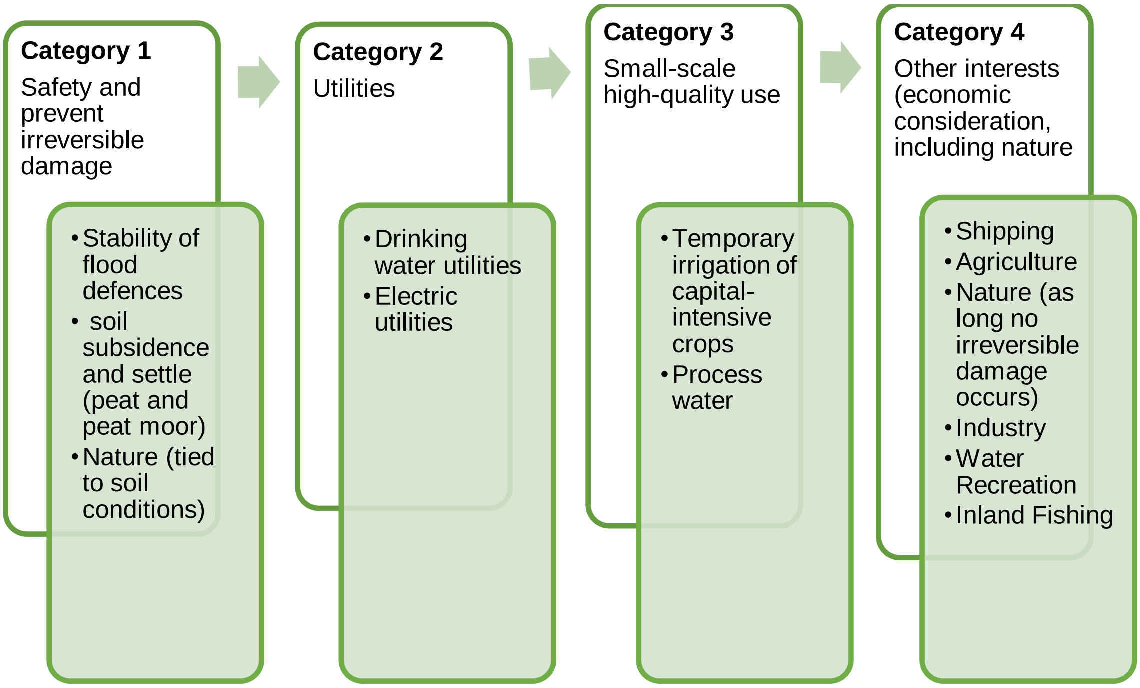

Figure 3. The water distribution priority sequence, adapted from *MIWM* (2009b)

2.4 State of the art of saline farming of quinoa

Quinoa is translated as: 'grain that grows where grass cannot grow'. The Andean crop has been recognized as climate resilient crop as it has the ability to maintain its rigidity and reduce transpiration (Choukr-allah *et al*., 2016). Its capabilites in combination with its nutritional value have led to global interest to introduce the crop in different (marginal)

[1] Artificial leaching refers to the method that prevents accumulation of excessive soluble salts in soils by the provisioning of more water than required to leach excessive soluble salts from the root zone (Corwin, Rhoades & Simunek, 2007)

agricultural production systems (Jacobsen *et al.,* 2003). This is illustrated by the initiative of the FAO to celebrate the year 2013 as the "Year of Quinoa" (Bazile *et al.,* 2016).

Quinoa is exported and imported already on a large scale. Dominant export comes from Andean countries, and is mainly imported by the USA, France and the Netherlands (Michel, 2012). Since 2013, quinoa is included in the assortment of all major Dutch supermarket chains and also the cultivation of quinoa is no longer unique to the Andean region, as new varieties are being cultivated worldwide (Wolkers, 2015). Europe counts an estimated production of several thousand tonnes, with France and Spain as leading producers. Although it is hard to compete with the volumes and production costs of South America, local quinoa supply is considered more sustainable which could be perceived as a competitive advantage (Janssens, Van den Berg, van Leeuwen & Jukema, 2008). The Dutch Quinoa Company, recently rebranded as The Quinoa Company (TQC), in combination with the Wageningen University and Research (WUR) plays a big role in this development, as it owns the licenses of many varieties suitable for European cultivation. The main varieties that are used in the Netherlands do not contain saponins[2] whereas the Andean varieties do (Choukr-allah *et al*, 2016). In the Netherlands, quinoa is cultivated by twenty breeders at approximately 100 to 250 hectare, resulting in a yield up to six tonnes per hectare (Wolkers, 2015; Acacia Water, 2020). In comparison; the average yield of wheat translates to 9-10 tonnes per hectare. However, wheat decreases to max. three tonnes per hectare under saline conditions, thus, making quinoa an interesting alternative in saline conditions (Acacia, 2020).

2.5 State of the art of saline farming of seed potatoes

In order to grow consumption or starch potatoes, a farmer needs to obtain seed potatoes. The world production of potatoes is expected to rise from 380 million tonnes to approximately 500 million tonnes by 2050 (MNLV, 2020). This development offers prospects for the entire Dutch potato chain (NAO, 2020), but especially for the seed potato sector as the Netherlands own 60% of the world trade of certified seed potatoes (MNLV, 2020). Seed potato cultivation is subject to strict quality requirements, i.e. needs to be free of pests and diseases. The NAK (Dutch General Inspection Service) regularly inspects this. As common diseases are mainly harmful to potato plants and not to humans or animals, rejected seed potatoes decrease in value but can still be sold as consumption potatoes (Nederlandse Akkerbouw, 2017).

[2] Plants create saponins to protect themselves against attacks from outside, for example bacteria, fungus and insects. They confer a bitter taste and should not be eaten (Choukr-allah *et al*., 2016).

The cultivation of (seed) potatoes is threatened by the occurrence of salinization (Blom-Zandstra *et al.*, 2014). Therefore, developments started regarding breeding more salt-tolerant varieties. Among others the Salt Farm Foundation (SFF) on Texel has carried out successful trials regarding the cultivation of over 200 potato varieties under saline conditions (Acacia, 2020). They concluded that currently fresh water remains necessary in the germination stage of the potato, but in further growth certain potato varieties are tolerant to salt-containing water, fertilizer and soil. Their trials mainly focus on table potatoes (e.g. 'Miss Mignon') since they are of high importance for worldwide consumption (Report Salt Farm Texel, 2016). As from 2014 there are also trials running in Pakistan with promising results: the salt-tolerant variety led to 28% yield increase under moderate saline conditions compared to the local variety. Thus, the varieties are approved by the government and cultivated by more farmers in the region (De Vos, 2019). Commercial breeders also investigate salt-tolerant potato varieties. For example, potato breeder C. Meijer B.V. started project ‘Proeftuin Zoet Water’ in cooperation with Deltares. They found moderate salt-tolerant potato varieties (i.e. ‘Melody’ and ‘Musica’). However, the root development was about 30% less and the growth of the plants in the saline part of the plot was significantly slower than in the in the control field (Report Proeftuin Zoet Water, 2017). Not many of other developments of salt-tolerant varieties of trading houses are publicly available, therefore additional information regarding the status of developments and diffusion within the sector is scarce. Numbers of the SFF estimate that their most popular salt-tolerant variety ‘Miss Mignon’ is cultivated on 35 hectares (Interview Marc van Rijsselberghe, 15th of May 2020).

2.6 Potential for combining quinoa with potatoes in the cultivation plan

When interested in saline cultivation due to increasing salinization, it is important to take into account that the whole cultivation plan should be salt-tolerant as farmers almost never cultivate only one cultivar (Bakel and Stuyt, 2011). Based on research, 11 of the 23 most commonly grown crops are sensitive to salts; e.g. winter carrots, (iceberg) lettuce and apples (Bakel and Stuyt, 2011). Moderately sensitive crops are e.g. winter wheat, sowing onions, maize and most potatoes. Crops such as winter wheat, cabbage, leek and chicory are moderately tolerant. Tolerant crops are grasses, sugar beet and quinoa (Bakel and Stuyt, 2011; ICBA, 2018). Furthermore, De Vos *et al*. (2018) identified white cabbage, red onion, broccoli, barley, seed potato and carrot varieties to be (moderately) tolerant. It is considered important to choose cultivars with the same salt-tolerance level. Quinoa is related to beet, thus resistant to beet diseases that threaten the yield. Therefor they are suitable in rotation. However, quinoa cannot be grown directly after the beet because of their conformity (Janssens, Van den Berg, van Leeuwen & Jukema, 2008).

Figure 4. Organic quinoa plot at Dutch Saline North Sea soil, June 2020

3 Methods

3.1 Theoretical frameworks

Within this research, two frameworks are used that have not been combined before. Firstly, for the interpretation and understanding of the value chain of quinoa and seed potatoes, the local value chain development (LVCD) framework (Herr, 2007) is utilized. The insights thereby obtained are incorporated to identify opportunities and constraints of the scaling of agricultural innovations as saline farming, guided by the multi-level perspective (MLP) (Geels, 2002).

3.1.1 Examining the value chain

For the identification of opportunities and constraints of the chosen products, it is advisable to examine the local value chain (Herr, 2007). As defined: "A value chain is a sequence of target-oriented combinations of production factors that create a marketable product or service from its conception to final consumption" and involves all activities that add value to a product (Donovan *et al.*, 2015, p.3). These activities can be executed by a single company, but often various firms are involved (Herr, 2007). LVCD aims to increase the competitiveness of a sector on the (international) market. To a farmer, market requirements within the value chain are often unknown, therefore they are unable to compete. In order to integrate themselves in markets and increase their competitiveness, firms need to be able to comply with market requirements and demand conditions. Market requirements are subject to negotiations between buyer and seller such as e.g.: delivery time, design and quantity, or demanded and executed through macro-economic policies. LVCD aids in the provisioning of insights within the sector and the market requirements, thus supports in the identification of opportunities for increasing competitiveness and scaling.

Figure 5. The General Value Chain, adapted from *Herr* (2007)

3.1.2 Examining scaling possibilities

The multi-level perspective examines why certain innovations scale, where others do not. The framework is developed to improve the interpretation and examination of the synergy between innovations and socio-technical transition processes (Geels, 2002). Transitions are assumed to result from interactions at three different levels; 1) the fast-changing niche, e.g. technological innovations and start-ups (micro-level); 2) the stable socio-technical regime, i.e. an established sociotechnical system with the aim of fulfilling a societal function (meso-level) and; 3) the slow-changing socio-technical landscape, i.e. material and immaterial elements such as infrastructure, social values and paradigms (macro-level). The levels are illustrated in figure 6. In general, the socio-technical regime is the result of interaction and dependency between actors and processes and not intentionally shaped. The rules within the sociotechnical regime influence and determine the interactions within the whole system. They form the starting point for the thinking and acting of actors, which often turns out to be focused on system optimization (maintaining the current regime) and not on system innovation. This results in states often being locked in a dominant way of doing, i.e. locked in the status quo (Rip & Kemp, 1996; Kemp & Geels, 2000). These lock-ins often involve power relations between groups, whereas one vest interest in maintaining the status quo, while others desire transition (Avelino & Wittmayer, 2016).

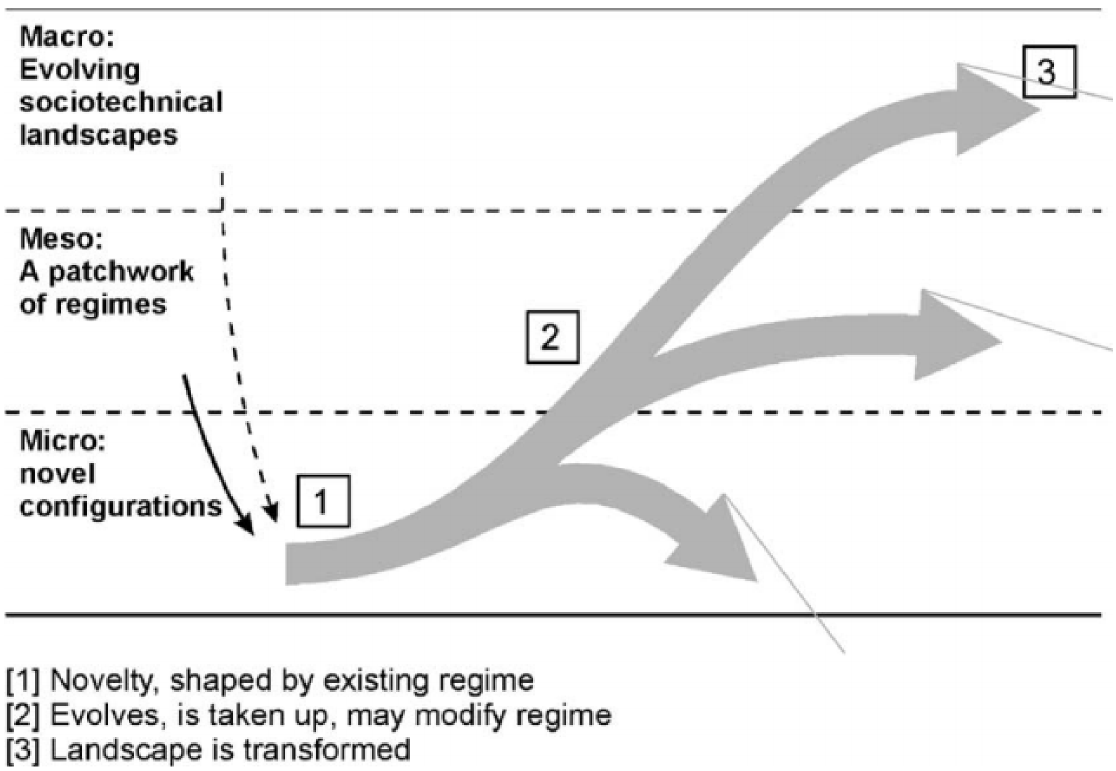

Figure 6. Formation and diffusion of an innovation, adapted from *Geels* (2002)

The MLP is the result of combining the described levels with the ongoing dynamics of six regime-dimensions: 1) industry; 2) technology; 3) policy; 4) science; 5) market, and; 6) culture. Inside of these dimensions there are different processes potentially slowing down or accelerating the innovation. Thus, the conditions of each level as well as the different dimensions within the incumbent socio-technical regime affect the performance of an innovation (Geels, 2002); e.g. a shock at the landscape level can result in the regime level to open up and the niche level to take over, leading to a breakthrough of a particular innovation (Hermans *et al.*, 2015).

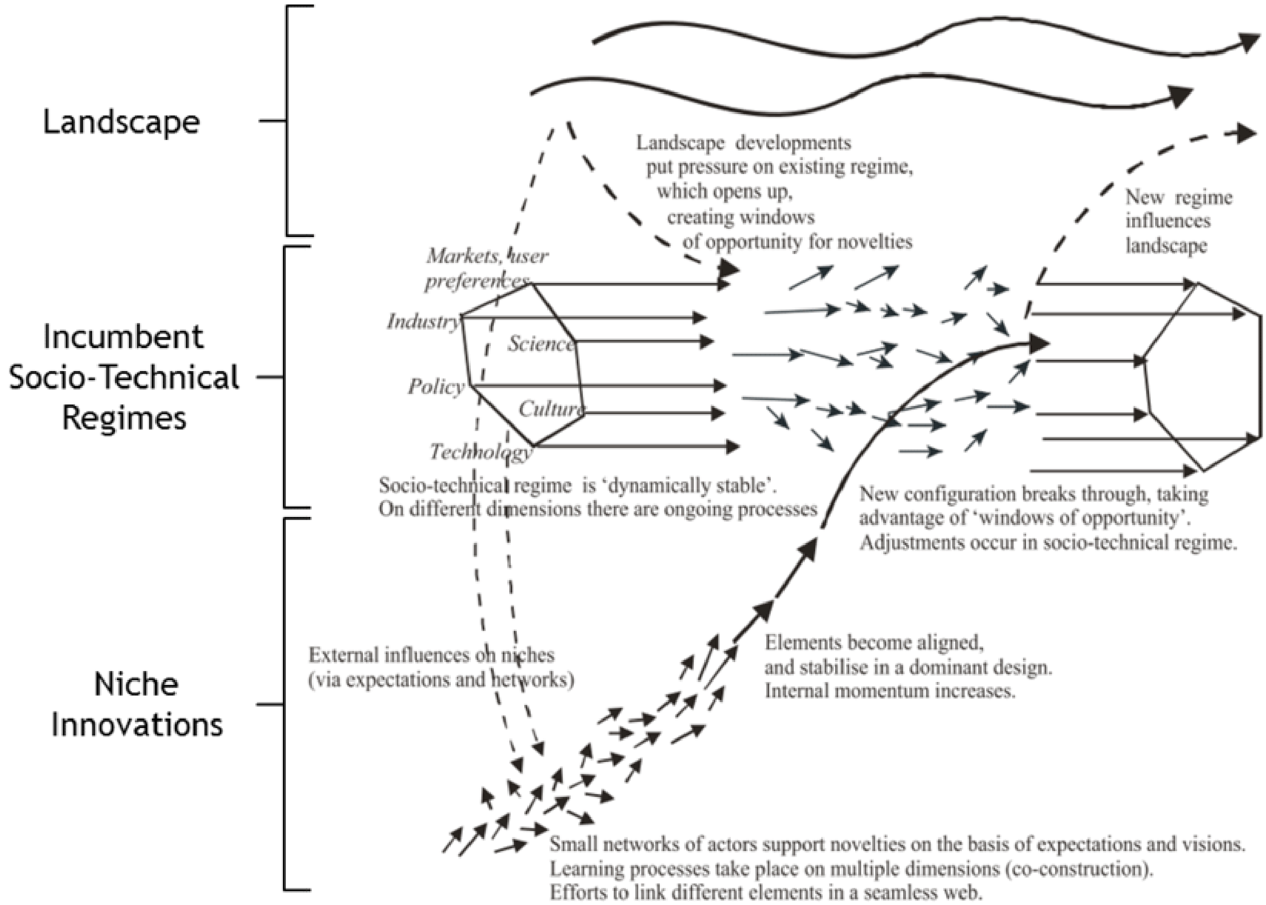

Figure 7. The multi-level perspective on transitions, adapted from *Geels* (2002)[3]

A regime undergoing a transformation is considered as a transition (Geels, 2004). The occurrence of such a transformation can be caused by pressure from either below, i.e. niche-accumulation, or above, i.e. slow processes or sudden shocks (e.g. Tsjernobyl). The system will resist but also adopt innovative elements from the niches (Geels, 2002). The conditions under which a niche may or may not be given the opportunity to grow are largely determined by strategies of actors and social mechanisms. These can accelerate, slow or break down the further development of a novel innovation such as saline farming. It appears that transitions only

3 This was the highest quality image of the framework to be found

continue if developments on one level can be linked to developments on other levels. E.g. new technologies must be in line with developments in markets, societal values and politics (Geels, 2002). In the case that such developments and processes are suitable for further growth of an innovation from the niche- to the regime and landscape level, this is defined a 'window of opportunity' (Rip, 2000; Geels, 2002). E.g. climate disasters are often seen as windows of opportunity as they trigger adaptive capacities, i.e. improvement of dykes after flooding (McSweeney & Coomes, 2011). The MLP identifies lock-ins and windows of opportunity, as well as other relevant aspects and dynamics potentially involved in the complexity of the scaling of innovations, to broaden the plethora of factors that must be considered when pursuing effective and sustainable scaling (Geels, 2005).

3.2 Research method

3.2.1 Local Value Chain Development

LVCD is applied to gain integrative perspectives on the development of the value chain of Dutch quinoa and seed potato production with saline farming practices. Therefore, firstly the value chain is examined and reconstructed, and opportunities and constraints within the value chain must be identified. An attempt will be made to specifically examine the market entrance, the market requirements and the demand conditions for quinoa and seed potatoes, and subsequently find out whether the actors within the value chain can or cannot comply to these requirements.

3.2.2 The Multi-level perspective

Supported by the MLP (Geels, 2002), various factors related to the complexity of scaling saline farming of quinoa and seed potatoes are mapped. In order to identify opportunities and barriers for the scaling of saline agriculture of seed potatoes and quinoa, the current socio-technical regime will be reconstructed and analysed based on the six dimensions of a socio-technological regime; industry, technology, policy, science, market and culture. Based on these dimensions, insights will be provided concerning the opportunities and barriers that arise. Thus, information can be gained into the driving or counteracting forces of the transition towards application of saline agriculture. Additionally, with the support of the MLP framework this research tends to identify potential lock-ins and windows of opportunity, i.e. gradual stress and sudden shocks within the landscape level. Thus, MLP provides insights in the interaction of a variety of dynamics involved in scaling, that could stimulate change but also lock current practice in its unsustainable mode (Geels, 2011).

3.3 Data collection

In order to obtain data to answer the research question, semi-structured interviews are held. This method allows for the discovery or examination of information that is perceived to be important to participants but may not have been thought of previously as the interviews consist of key questions that aim to define the target subjects to be explored, but also gives the interviewer or interviewee the flexibility to deviate in order to be more elaborative regarding a certain topic (Gill *et al.*, 2008). It is aimed to include different actors concerning the value chain as well as experts, including a balance between interviewees from the regime- and niche-level. Guided by the snowballing method, potential interviewees have been identified. By means of a starting and entry point, experts involved in the SalFar-project where interviewed first. Following the snowballing method, the subsequent interviewees were based on recommendation and referral (Bryman, 2012). This led to 33 interviews in total, of which 1) four with representatives and seed potato experts from among the biggest trading houses, i.e. HZPC, Meijer B.V., Solynta and Agrico; 2) six with farmers, i.e. two quinoa farmers, three seed potato farmers, one both, of which three had salinity issues; 3) two with representatives from the retail, i.e. Quinoa Holland and Marc.Foods; 4) four with policy-makers, i.e. Ministry of agriculture, province of Friesland and water boards Rijnland and Wetterskip Frysland; 5) four with sectoral representatives, i.e. Potato-valley, LTO-Noord, Boerenverstand and Royal General Union for Flower bulb culture; 6) five expert interviews, i.e. one regarding salinization and four regarding salt-tolerant crops as adaptation strategy ; 7) six interviews focussed on the quinoa value chain within the Netherlands, i.e. The Quinoa Company (TQC), Mercadero, GreenFood50 (and owner of LOLA Quinoa[4]), ICBA, WUR and Quinoa Lokaal (ILVO); and 8) two with experts from informative bodies, i.e. PBL and STOWA. To broaden the scope of this research, three interviews were conducted with foreign experts, i.e. two from Belgium (Instituut voor Landbouw- Visserij- en Voedings-onderzoek) and one from Morocco (International Center for Biosaline Agriculture).

The interviews where recorded, summarized, coded and analysed based on overarching or differentiating outcomes. In order to be comprehensive, results are presented with the support of a scale that identifies the quantity of interviewees that agree on a certain topic; i.e. *few; <4 (-/+), multiple; 5-20 (--/++) and many; >20 (---/+++)*. This is a wide range as the expertise of the interviewees vary, e.g. quinoa experts did not elaborate upon the seed potato sector. To

4 LOLA (i.e. LOwLAnds) is a brand of GreenFood50 specialized in quinoa ingredients from Dutch soil

support the results, quotes will be given. The quotes are coded based on the order above with: TH1- 4 (*trading houses (potatoes))*, F1- 7 (*farmers*), R1-2 (*retail*), PM1- 4 (*policy-makers*), SR1- 4 (*sectoral representatives*), E1- 5 (*experts*), QE1- 6 (*quinoa (value chain) experts*) and IB1- 2 (*informative bodies*), An overview of the interviewees can be found in the appendix.

3.3.1 Reliability and validation

In order to secure the reliability and validity of this research, several means are used to increase its external reliability, internal reliability and validity. The research method, to begin with, is described in detail, aiming to support replicability. Summaries of the semi-structured interviews and the coding of lock-ins and windows of opportunities are not standardly included due to privacy reasoning; however, they can be requested for inspection in consultation. A valid research is expected to entail corresponding observations and theoretical conclusions (Bryman, 2012). This is ensured by the use of data triangulation, which is considered a suitable validation method that entails the combining of various sources to answer the research question: 1) scientific articles; 2) policy documents and; 3) interviews with both stakeholders and experts. As such, data triangulation is expected to give a balanced description of a situation (Altrichter *et al.*, 2008).

4 Results

In order to identify opportunities and barriers for the scaling of saline agriculture of seed potatoes and quinoa the value chain of both products is given. Based on the value chain the market entrance and market requirements are analysed. Furthermore, a description of the six dimensions (industry, technology, policy, science, market and culture) of the socio-technical regime of quinoa and seed potatoes is given. Supported by the interviews, insight will be provided into the opportunities and barriers that may arise in the various dimensions as well as the roles actors play in this. In this way, the driving or counteracting forces of the transition to the scaling up of saline agriculture can be grasped. Furthermore, potential lock-ins and windows of opportunities that arose from the interviews are identified. Based on the interviews, the different levels are identified as:

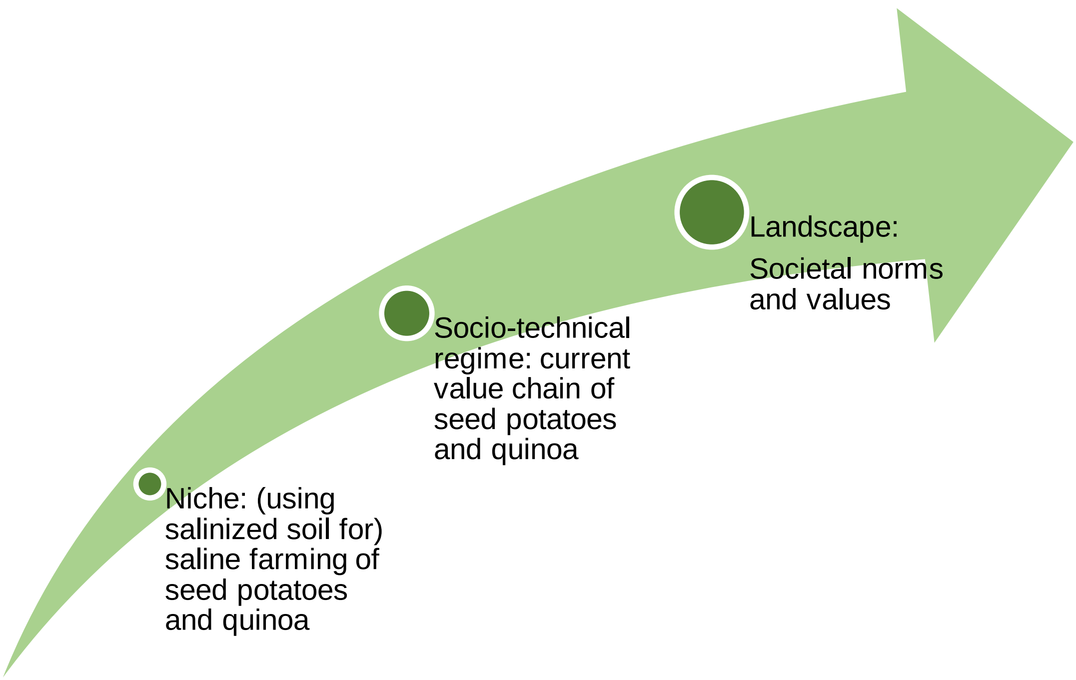

Figure 8. The different levels, adapted from *Geels* (2002)

4.1 *What does the value chain of the saline farming of quinoa and seed potatoes look like?*

Based on the interviews, the value chain of both products in the Netherlands looks as follows:

4.1.1 Quinoa

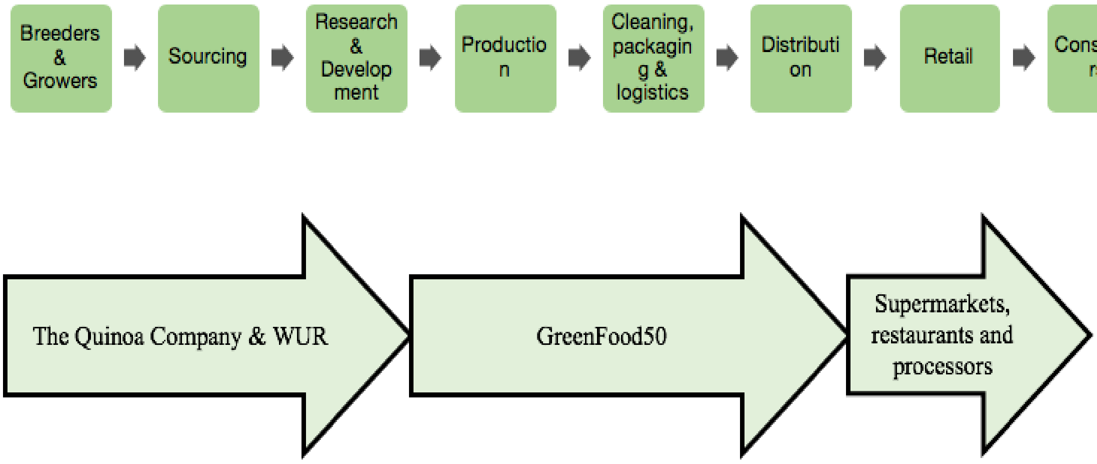

Figure 9. The value chain of Dutch quinoa, adapted from *Herr* (2007)

4.1.2 Seed-potatoes

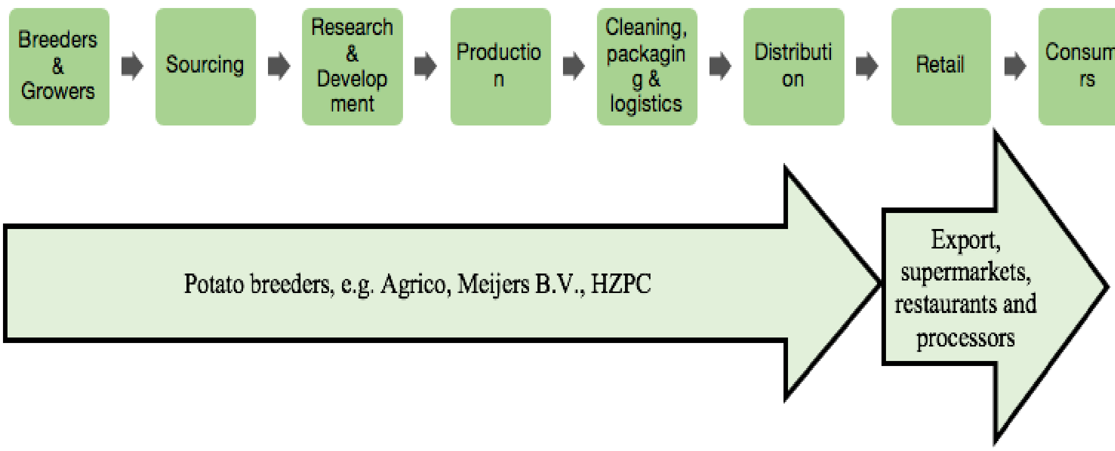

Figure 10. The value chain of seed potatoes, adapted from *Herr* (2007)

4.2 What are the opportunities and constraints for scaling of quinoa and salt-tolerant seed potatoes based on the value chain?

Based on the value chain of quinoa and seed potatoes, findings concerning the market entrance and market requirements came to light. At the end of the paragraph, an overview of the identified requirements and the ability to comply determined by the interviews is given.

4.2.1 Quinoa

Market entrance

Around thirty years ago the Wageningen University (WUR) pioneered in quinoa-breeding, aiming to develop a variety suitable for European (and preferably Dutch) conditions. They started to market the developed varieties under The Dutch Quinoa Group, currently re-branded as The Quinoa Company (TQC): "*as a commercial company* (i.e. TQC) *we basically trying to do the job that WUR cannot do; commercialization"* (QE1). There is no free market for quinoa in the Netherlands as TQC owns the licenses of suitable varieties. GreenFood50 obtained the responsibility for the production and distribution of the WUR/TQC varieties; "*the quinoa grown here is developed by the WUR, owned by TQC and marketed by GreenFood50"* (QE4). GreenFood50 manages the demand and supply for quinoa; if there is no increasing demand, no new farmers are needed, thus you are not allowed to grow quinoa.

Market requirements

It was indicated that the original quinoa variety, 'Royal Quinoa', is a protected Andean variety. The variety looks very white and polished, is quite large and contains saponins, thus needs to be washed and polished thoroughly. Dutch quinoa differs and is saponin free: *"the quinoa here is less white, also because it is washed less as it contains no saponins. You can think of it as whole grain quinoa"* (QE4). *All quinoa experts* identify **the common characteristic of the Royal Quinoa as a market requirement** as *"people are already very accustomed to a certain kind of quinoa: white. This makes it difficult for retailers to sell local quinoa because it looks different"* (QE3). Additionally, QE1 adds that in between Dutch varieties also a standard is set; *"there is a standard type of Dutch quinoa that can be sold in the market, and everything else must be sold at a lower price to e.g. millers"*. Moreover, **the country of origin is identified as important** by *a few*: *"people are used to quinoa coming from Peru or Bolivia. Maybe they think that Dutch quinoa is less good"* (QE3). However, *multiple* state that for **consumption the types are similar.** Thus, the Dutch variety can be used for the same things as the Andean.

In general, *multiple* identify **more demand for organic quinoa then conventional quinoa**: "*the prices of organic crops are much higher than those of conventional crops, in fact twice as high"* (QE4). Therefore, it is of importance to gain or obtain organic certificates. This is possible, however expensive. The retail sector is aware and are considered by QE4 to value the label 'organic' over 'local'. This is illustrated by the fact that Albert Heijn pressures LOLA Quinoa to become organic *"because otherwise it has no added value for them as they already have conventional quinoa themselves"* (QE4). This relates to the market requirement regarding pricing. *Multiple* identify **local quinoa to be more expensive than conventional quinoa**. That makes retail difficult "*as quinoa is an expensive product, consumers are expected to choose the product with the lowest price"* (QE3). The higher price results from higher labour costs, the labour-intensive production process and the high investments regarding certificates. Besides: "*the Dutch soil is expensive. Many products can be produced cheaper abroad"* (QE4). Table 1 provides an overview of the identified market requirements and the ability of the Dutch quinoa to comply.

Market requirement	**Identified by**	**Possibility to comply**	**Comment**
Characteristics of Royal quinoa (i.e. white, polished and large)	8	No	Royal Quinoa is protected, Dutch varieties differ (i.e. darker and smaller)
Country of origin (i.e. Andean)	3	No	Dutch quinoa is produced in the Netherlands
Consumption purposes	3	Yes	Dutch quinoa is applicable to the same consumption purposes as regular quinoa
Organic certificates	5	Yes	Certifications are expensive but possible to obtain
Pricing	8	No	Higher labour costs, labour-intensive production, high investments for certificates and expensive soil lead to higher prices

Table 1. Market requirements of quinoa in the Netherlands

4.2.2 Seed potatoes

Market entrance

There are multiple different trading houses specialized in seed potatoes. Trading houses own breeding programs aimed to develop new varieties to be licensed and taken to the market: *"we want to register new varieties for Plant Breeding Rights, which is similar to a patent. If it meets the requirements you get a license; the Plant Breeder's Rights Protection. This lasts 30 years for potatoes"* (TH1). Farmers produce seed potatoes for the trading houses through contracted cultivation. The amount to be produced is agreed on forehand and thereby the farmers are secured of revenue and take-off. What kind of seed potatoes farmers cultivate depends, as *all* trading houses agreed that supply follows demand. This is also the case for (more) salt-tolerant varieties, as long as there is no (high) demand, trading houses indicate that they will wait with development and subsequently cultivation.

Market requirements

As stated by *all* trading houses, seed potatoes are produced mainly for export. Therefore, market requirements are often set by the location exported to. However, there are a couple of overarching requirements identified during the interviews. Firstly, *many* agree that there needs to be determined whether the potatoes grown from seed potatoes need to be consumed freshly as a table potato or need to be processed for fries, chips or starch. This poses problems, according to *multiple*. As E2 explains: *"salt-tolerant potatoes produce more sugars, when fried or baked they turn brown*". Thus, they are unsuitable for the chips and fries-market. Currently "*50% of the world market demands fresh potatoes, i.e. unprocessed"* (TH2), so for those areas this may not be an issue. However, TH2 and E4 identify that for western countries, including the Netherlands, processed products are more important. Thus, there is need for salt-tolerant seed potato varieties that could be applied for these purposes: "*there is demand for a salt-tolerant potato, built up in the Netherlands as a seed potato and exported to a country where it can grow into a consumption or starch potato. It must then be able to be used for the correct processing (e.g. frying) and close to existing cultivation; it remains a seed potato, but one that can withstand higher salt values"* (E4). However, *multiple* state that **such a variety is not yet developed**.

A few also identify the difference between salt-tolerant varieties and common varieties as an opportunity for the niche market, where they are interested in differentiating products. However, this is only a small market and certainly not bulk: "*we notice that there is a market in those special salt-tolerant products you don't need a lot of: purple crisps or purple potato,* *for decoration in a restaurant"* (F3). In this market they prefer products that *"are actually only interesting if they are distinctive in taste or appearance"* (E1). Additionally, E2 states that there are indications that salt-tolerant consumption varieties are healthier than regular varieties. This could fit in the prevailing idea of 'the healthier the better' and therefore one "*could even sell them for more money"*. However, **this does not apply to seed potatoes specifically**, but to the potatoes that grow from them. Additionally, the volumes a variety produces matters. *Multiple* state that, currently, **salt-tolerant varieties on average produce a lot less in terms of absolute volume**. Therefore, a high-productive but salt-sensitive seed potato variety can lead to a higher absolute value then a low-productive salt-tolerant variety. As SR3 illustrates: *"Salt-tolerant itself says little; you also have to think about the volumes. A salt-tolerant variety can give less volumes under saline conditions than a highly productive variety that is not salt-tolerant of which half fails."* An overview of the identified market requirements and the ability of the salt-tolerant seed potatoes to comply is presented in table 2.

Identified Market Requirement	**Identified by**	**Possibility to comply**	**Comment**
Purpose of consumption	8	Yes and no	Possible for processing and table potatoes; not for chips and fries
Non-differentiating product (e.g. regular seed potato)	10	No	Not yet developed
Differentiating niche product (e.g. purple coloured)	2	Yes	The niche market currently has only little demand
Salt-tolerant varieties must be competitive to regular in volumes	8	No	Salt-tolerant seed potatoes are currently less productive then regular seed potatoes

Table 2. Market requirements of seed potatoes in the Netherlands

4.3 What are the opportunities and constraints that rise from the dimensions of the current socio-technical regime of quinoa?

A wide variety of actors are interviewed to get a clear view of the opportunities and constraints within the sociotechnical landscape of quinoa. This landscape is built upon six dimensions; industry, technology, policy, science, market and culture. Each coming paragraph focusses on one of them. At the end a comprehensive overview of all dimensions together is presented, combined with a weighing based on importance based on the number of interviewees endorsing a certain opportunity or constraint, i.e. *a few* (-/+), *multiple* (--/++) and *many* (---/+++).

4.3.1 Industry

There are only a few companies active in the Dutch quinoa sector; WUR, TQC and GreenFood50. The quinoa is developed by WUR and TQC and produced and distributed to the retail sector by GreenFood50. Dutch quinoa is sold to processors (e.g. Danone), wholesale (e.g. Sligro), supermarkets (e.g. Ekoplaza and Spar), online stores (e.g. Pit&Pit) and restaurants (e.g. La Place). Farmers produce quinoa for GreenFood50 by contracted cultivation, which means that a pre-agreed amount will be purchased at a fixed price: *"they* (i.e. GreenFood50) *contract farmers to grow quinoa; farmers grow the quinoa for them under very strict conditions and at the end of the season they have to buy that quinoa"* (QE2). This led to the following findings:

1) Within the industry dimension of the sociotechnical landscape of quinoa there is no free market. The fact that there are scarcely any actors within the sector is identified as constraint by *multiple* interviewees, as the rights to cultivate quinoa suitable for Dutch cultivation is managed carefully by GreenFood50: "*you can assume that 95% of the quinoa grown in the Netherlands goes through us* (GreenFood50)*. You may not secretly collect and grow our seeds and sell them, because then you are violating the breeder* (TQC and WUR) *who has invested 20 years in it"* (QE4). Thus, a farmer (or even a hobby-gardener) is not allowed to buy or sell seeds if GreenFood50 does not demand them too. F6 endorses this problem: *"We signed up to grow quinoa and have been on the waiting list. That means for now we cannot grow quinoa, even though we want too"*. Besides, as GreenFood50 manages supply according to the demand, there is no guarantee that the requested supply is constant. Thus, if you cultivate a certain amount of quinoa one year, and the overall demand decreases, the amount you are asked to cultivate could be halved next year. This dependency hampers the uptake of quinoa as an option for farmers who struggle with increasing salinization, as the (trade of the) pseudo-grain is currently simply not freely accessible.

2) There is lacking competition because of lacking profit. Less mentioned was the lacking competition. However, this is perceived as an important constraint by *a few*, as it results in the sovereignty of the mentioned companies. Others are able and welcome to compete with WUR, TQC and GreenFood50, but this has not happened yet. According to QE5, current results of TQC show that the viability of quinoa cultivation within the Netherlands is very difficult, even for TQC: "*first, you need more demand to make cultivation profitable in the Netherlands and before a competitor would be of value*" (QE5). Therefore, competition awaits.

Opportunities	Constraints
	No free market --
	No competition -

Table 3. *Identified opportunities and constraints from the industry dimension of quinoa*

4.3.2 Technology

Insights in the technology dimension of the quinoa sector is mainly provided by WUR and TQC. They are constantly aiming to develop technology that smoothens emerging problems: "*our intention is to bring technology that no one yet brings to quinoa, so people have access to seeds that can compete to seeds like maize and other cereals*" (QE1). The technological problems arisen from the interviews are stated as follows:

1) The cultivation of quinoa must be pesticide-free; thus, the whole cultivation plan must be pesticide-free. A prevailing issue within the technological dimension, highlighted by farmers as well as various experts and developers, is the fact that quinoa needs to be cultivated without the use of pesticides due to legal jurisdictions. This means that the whole cultivation plan must be pesticide-free. *All* farmers indicate this and resulting weeds as a constraint: *"I wanted to quit a few years ago, as the weeds were too annoying."* (F5). Some solved this by putting clover after quinoa in the cultivation plan, thus it can be mowed and be integrated in the 'grass'.

2) Dutch quinoa has a technological advantage as it is saponin-free. An aspect that is identified by *multiple* to smoothen the technological process of quinoa cultivation, is the absence of saponins in Dutch varieties. This saves time and money for producers and consumers. The fact that Dutch quinoa contains no saponins is considered *"a huge advantage* *that makes it competitive to South-America. If it would contain saponins it would be at least 30% more expensive"* (QE1).

3) The cleaning- and processing facility for Dutch quinoa is located in Zeeland. Regardless the absence of saponins, still the quinoa needs to be sorted and cleaned. This takes place in a factory in Zeeland, which leads to technological problems regarding the distance from producers in the northern part of the Netherlands. As F3 states: *"it's not convenient to cultivate quinoa if I have to transport the harvest from Terschelling to Zeeland"*. Thus, a cleaning and packaging facility at a central location is identified as an opportunity by a *few*.

4) Sowing practices are difficult. QE5 identified that for production, the practices regarding the sowing are currently still very difficult: "*that measures very closely. You can't sow it too deep because it is a small seed but sowing it shallow has the risk of drying it out"* (QE5). There is no sufficient machinery for these tasks, as identified by QE5.

5) The volumes of the quinoa are (too) low and unstable. A trade-off due to low productivity is identified by a *few* interviewees. As QE3 illustrates, you have to choose between *"more volume but lower price per product* (e.g. tarwe), *or less volume and higher price per product* (quinoa)*"*. A supplementary problem identified by one interviewee is that the *"most popular variety 'Duchess' gives most volume, but is also big so if there is a lot of wind it can be damaged (kinked)"* (QE4).

Opportunities	Constraints
Saponin-free ++	Pesticide-free cultivation --
Cleaning and processing facility in a more central northern area +	Cleaning and processing facility in Zeeland -
	Difficult sowing practices -
	Low and unstable productivity -

Table 4. *Identified opportunities and constraints from the technology dimension of quinoa*

4.3.3 Policy

There are instruments and initiatives identified from the policy dimension that (would) support or obstruct the uptake of Dutch quinoa cultivation:

1) In 2013 FAO initiated the 'international year of quinoa (IYQ)' with the objective to increase awareness of the benefits of quinoa. These benefits entail the biodiversity and nutritional value of quinoa that could play a big role in food security, nutrition, and poverty eradication. IYQ resulted in the establishment of TQC because of "*the opportunity to create a market for local quinoa because of the increasing awareness and demand*" (QE1).

2) Lacking authorization of pesticides obstructs the scaling of quinoa cultivation. *Multiple* interviewees within the sector state that the lack of jurisdiction regarding pesticides negatively influences the quinoa cultivation (and thus consumption): "*in Europe pesticides have to be authorised per crop, per purpose. Nothing is allowed for quinoa. This makes it more difficult to grow quinoa here*" (QE3 endorsed by *multiple*). This has various reasons: "*it is a matter of slow regulation, but also the fate of smaller crops because tests are expensive*" (QE4 endorsed by QE3 and F6). Others agree regarding the difficulty of the admission procedure: *"the investment is too high, compared to the revenue it generates. This does constrain scaling of quinoa cultivation in the Netherlands"* (QE5).

3) Lacking guidance from the governmental agents obstructs the scaling of quinoa cultivation. In general, if you want to support the use of marginal soils or water resources for agriculture, *"you need schemes and subsidies that support these farmers to get a better return out of their practices by helping them push the price lower than the costs to produce"* (QE1). This is endorsed by farmers as well as experts, however, no such instruments are identified.

4) Recently TQC acquired a 2M grant to research the salt-tolerance of quinoa and its potential as a protein staple crop. As being said, there are no general governmental subsidies and schemes regarding the acceleration or support of quinoa cultivation in the Netherlands identified. However, TQC recently received an investment of €2M to further examine the salt-tolerance of quinoa and its ability to be produced in bulk. Whether this is public or private money remains unclear. QE1 explains: "*we have noticed that you cannot get that much research money unless there is a company involved; all investments need to bring something to the country*".

Opportunities	**Constraints**
Year of Quinoa (2013) ++	Slow authorization of pesticides --
2M grant for research salt-tolerant quinoa as staple crop +	High investments for admission procedure pesticides --
	No general schemes and subsidies -

Table 5. *Identified opportunities and constraints from the policy dimension of quinoa*

4.3.4 Science

Within the science dimension the opportunities and constraints rising within the scientific field concerning Dutch quinoa cultivation is presented. In general; *"if TQC can develop better varieties and have better knowledge of how to grow it, this also makes it possible to grow it more cheaply"* (QE3). There are various themes within the science dimension identified that need attention:

1) Dutch quinoa research is relatively underdeveloped. *Multiple* interviewees identified that the time that quinoa has been researched and developed in the Netherlands is only a short period of time in comparison to established cultivars, thereby taking into account the timeframe of variety-development. The development of new varieties can take 15 years. Thus, you have to look ahead, also concerning salt-tolerance: *"the reason why we are working with salt-tolerant species today, is that when you start breeding, this development can take 15 years"* (QE1).

2) Quinoa needs to become better protected to external threats and the production of quinoa has to become more stable in terms of volume. Quinoa needs to become better protected to weeds, insects and fungus in an organic way, as no pesticides are allowed: *"research needs to be done to find out what does not damage the quinoa but the weeds and threats"* (QE5 endorsed by *a few*). When looking at the production, the variability of the crop needs to be examined: "*we have 4 hectares; one year 2000kg is produced, the other year 2500kg. The exact reason is still unclear, there is not enough knowledge about that"* (F2 endorsed by *multiple*). As the volume of the yields vary, constant revenue is not guaranteed.

3) For the end use, *many* identify that consumer-preference research needs to be executed. According to *many*, there is a knowledge gap within the Dutch consumer preferences regarding quinoa. The reasoning of consumers to make certain choices is therefore subject to guessing at the moment. Market research however is currently not easy, as *a few* identify that GreenFood50 is rather closed regarding their sales.

Opportunities	Constraints
R&D of Dutch quinoa is relatively 'young' ++	Unclear why volumes vary --
Organic pesticide protection +	No free information regarding sales -
Consumer preferences +++	

Table 6. *Identified opportunities and constraints from the science dimension of quinoa*

4.3.5 Market

The market dimension tends to examine what drives actors to act in a certain way. For example, WUR and TQC gain revenue from the development of varieties to license. This is not without a reason: *"you have to understand that if I give you quinoa seeds, you can multiply it forever. As a breeding company, therefore we have no business"* (QE1). Their quinoa genetics are currently cultivated in Europe, North and South America and Asia. The following opportunities and constraints within the market dimension are identified:

1) The demand is expected to grow, but likewise the international supply is growing. *Multiple* interviewees state that they expect the local quinoa sector to grow due to increasing consumer interest. Thus, the supply is increasing as well: *"the market itself is growing very fast, but there is also more and more supply from Europe, Spain and France but also from Canada and (South) America"* (QE3). In general, the prevailing belief identified by *multiple*, is that for quinoa to be competitive on the (international) market, you need to do it in bulk: "*LOLA quinoa has been successful because we put a lot of marketing money in the concept. Those efforts only work if you can concentrate investments, and if you can give high volumes*" (QE1). This is not yet perceived to be the case according to *multiple.*

2) There is a higher demand for organic quinoa, however, organic certificates demand high investments. The price for organic quinoa is higher and the sales are bigger than for conventional produced quinoa. To acquire organic certificates (e.g. Skal) the whole cultivation plan needs to be produced biological. *Multiple* identify the high investments in order to gain such a certificate as a constraint. As F6 states: "*we are on our way to become organic, but not yet Skal certified because that costs a lot of money".* Imported quinoa often has such certificates, however *a few* interviewees state that is unclear to what extent these have been acquired fairly as *"there's a lot of corruption in the market. Recently there have been recall campaigns at the Action* (i.e. store) *for example, where organic quinoa contained pesticides"* (QE4). As a result, a difference in perspective of organic and conventional farmers becomes clear. Whereas the organic farmer is content with the current situation, "*you don't have to worry about sales or anything like that"* (F5); the conventional quinoa cultivator is less satisfied: "*In the beginning when TQC started, they came up with great plans and nice financial prospects, but that turned out to be very disappointing"* (F2). *Multiple* state that this distinction results from the different prices for organic and conventional quinoa.

3) One interviewee identified competition from other (pseudo-)cereals and grains as a constraint. *"We do notice that customers exchange quinoa with oats or buckwheat when the price rise too much"* (QE4). However, others did not identify this.

4) The novelty of quinoa itself smoothens marketing. The fact that quinoa is a new local crop also benefits, according to multiple: "*you don't have to market it specifically because it's already a new product"* (E5). Therefore: *"we will not indicate that our quinoa comes from saline soil. This is irrelevant to us"* (QE4).

Opportunities	Constraints
Growing demand for quinoa ++	Growing international supply --
Big demand for organic quinoa ++	High investment for certificates --
Novelty good smoothens marketing ++	Corruption in certification of imported quinoa -
	Replaceability by other (pseudo-)grains -

Table 7. *Identified opportunities and constraints from the market dimension of quinoa*

4.3.6 Culture

Within the cultural dimension of the sociotechnical regime of quinoa, the symbolic meaning is described. The cultural or symbolic elements that were identified to influence the sociotechnical regime of Dutch quinoa cultivation are highlighted in the following paragraphs:

1) Focus on added value. Research and development is mainly driven aiming to add value; "*if you invest in under-utilized plant species, you can actually add more diversity to food production systems"* (QE1). TQC is motivated to make quinoa a global staple crop, by delivering genetical innovations and seed technology that enhance global large-scale and profitable cultivation: *"our objective is to accelerate the evolution of quinoa, so it can enter professional farming systems"* (QE1). Increasing food demand is identified by multiple of importance as well; "*in 2050 we must produce 70% more food. That won't come from saline agriculture only, but we need to use the saline resources for conventional crops to reach that 70%"* (E2). Thus, "*we have to look ahead; climate change will lead to more saline soils around the world and quinoa can be one of the solutions to it"* (QE1).

2) Curiosity regarding (business-opportunities and sustainability of) quinoa drives farmers to cultivate. In the interviews, experts mention that often the idea that '*what a farmer doesn't know he doesn't want'* is grounded (E2, E3 and SR1), however, this is not perceived true by the interviewed farmers. They argue; *"I like to try new things and quinoa is a healthy crop, a crop to be proud of"* (F5) plus *"the reason we want to grow quinoa is that we are looking for a novel and profitable crop"* (F6). Additionally, the sustainability issue is of value: "*for farmers, growing this product is good for biodiversity and keeps the soil healthy"* (F4).

Also, the long-term vision plays a role: *"many generations after us must be able to live off the land. Given the high demand for food for the ever-growing world population, this is a very important issue for us"* (F4). F6 adds: "*I'm looking for salt-tolerant crops to keep the soil healthy for the next generation. My successor should be able to cultivate too"*.

3) The importance of traceability and sustainability. For retail and distribution, it is mainly the value of 'local', traceability and sustainability that has been identified by *multiple* to make the concept of local quinoa powerful. As QE1 argues: "*you need to educate the population about the benefits of having locally grown, traceable food".* Same for firms: "*if you want to do it right, besides organic, quinoa has to be local. We* (GreenFood50) *are talking to companies that import organic quinoa from the Andes about this"* (QE4).

4) The need for a transition from a specialty to an established crop. *A few* interviewees identified that the problem with quinoa is that people see it as a specialty crop and therefore *"you need to compete in a specialty market where prices are important"* (QE1). This can result from the fact that the consumption of quinoa is not embedded in the Dutch culture. Therefore, it is important how you market it. *A few* state that you should sell quinoa as an alternative: *"when you introduce a new crop and you can offer it as an alternative to something very similar, that you can replace it easily, the threshold for the consumer is lower"* (E2). This could entail e.g. rice or couscous. That quinoa is not culturally embedded also influences the pesticides use: *"e.g. wheat and maize can be developed with a lot of pesticides… it is from the historical point of view that new crops are watched more closely than old ones"* (QE3).

Opportunities	Constraints
Increasing importance of 'adding value' +	Unknown to farmers -
Curiosity regarding new cultivars +	Labelled as specialty crop -
Increasing value of 'local', 'sustainability' and 'traceability' ++	Not embedded in our culture -
Easy alternative for established cultivars +	

Table 8. *Identified opportunities and constraints from the culture dimension of quinoa*

4.3.7 Interim conclusion

The main findings concerning opportunities and constraints rising from the different dimensions of the sociotechnical regime of Dutch quinoa cultivation are illustrated in the figure 11. The dimension that show the most opportunities are located left, and the dimensions that pose the most constraints are located right. The weighing is based on the importance of the opportunities and constraints identified, i.e. the number of total minuses (-) and plusses (+). Market is in both rows as the identified outcomes where of equal weight.

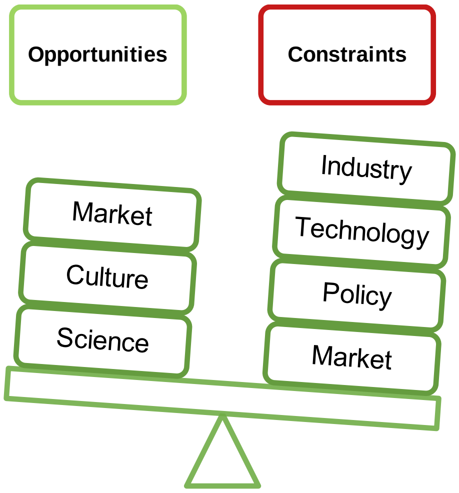

Figure 11. Supporting and obstructing dimensions of the sociotechnical regime of quinoa.

4.4 What are the opportunities and constraints that rise from the dimensions of the sociotechnical regime of salt-tolerant seed potatoes?

4.4.1 Industry

Trading houses and farmers are identified as main actors within the industry dimension of the sociotechnical regime of seed potatoes. Trading houses develop and distribute varieties to the export and the retail sector, farmers cultivate demanded varieties through contracted cultivation. Additionally, the scientific field also researches and develops salt-tolerant seed potatoes.

1) More cooperation between actors is needed. Research and development regarding salt-tolerant varieties is executed in both the commercial field as the scientific field and is supported by governmental agencies, e.g. ministries. However; *"researchers would like to cooperate more with the trading houses"* (E1). This is identified by *a few* as a constraint for acceleration of the development of suitable salt-tolerant varieties and is identified to result from:

2) Contradicting motivation of actors. *Multiple* identify the fact that the trading houses focus on increasing revenue, whereas the scientific field does not have a commercial aim, makes it hard to cooperate. As illustrated, there is cooperation within fundamental research, but the development of salt-tolerant varieties is separate. What could be of importance here is that the main revenue for trading houses comes from licensing varieties, thus: *"it is a bit of a minefield, because a breeder likes to have a salt tolerant breed in his assortment, but he doesn't like it when it comes out that his assortment turns out to be sensitive to salt"* (E2). As E1 illustrates: "*assumingly 70% of their* (i.e. trading houses) *varieties are not salt-tolerant. If they have to take them out, it will cost them 200-300 million"* (E1). Trading houses explain: *"closer to what you want to put on the market, there is no cooperation because of competition"* (TH1).

1) Research is becoming more accesible. In general: *"doing research in the potato world is becoming easier and cheaper. It was very expensive a few years ago, but prices are dropping due to available technology. As a result, we start to understand complex things better and better"* (TH3 endorsed by *few*).

Opportunities	Constraints
Research is becoming easier and cheaper +	Not enough cooperation between actors -
	Contradicting motivation of actors --

Table 9. *Identified opportunities and constraints from the industry dimension of seed potatoes*

4.4.2 Technology

1) The development of salt-tolerant varieties close to existing cultivation is not acute, but urgent. As E5 aptly describes; *"Salinization is not an acute problem, but the development of saline agriculture and salt-tolerant varieties is urgent*" (E5). *Multiple* identify the technological quest of trading houses and research institutes to develop a salt-tolerant potato variety that is close to existing, regular cultivation: *"it must remain a common seed potato, but one that can withstand higher salt values"* (E4).

2) The need for organic varieties is winning ground. *A few* interviewees identify the subsequent requirement for salt-tolerant seed potatoes to be grown organically. However, this is considered difficult as current varieties are already hard to produce organically. Thus, the development of organic common varieties (non-salt-tolerant) is prioritized over salt-tolerance, as the demand for the first is bigger.

3) Hybrid breeding is being developed. The quest for appropriate varieties will potentially be smoothened thanks to the emergence of hybrid breeding, as identified by *a few*. This goes faster and is therefore cheaper. Solynta is a firm focussed on this technique and expects to present their seed-potato seeds late 2020.

Opportunities	Constraints
Hybrid breeding on the rise +	Must be similar to common potatoes --
	Development of organic varieties is prioritized over salt-tolerant varieties (or the combination of both) -

Table 10. *Identified opportunities and constraints from the technology dimension of seed potatoes*

4.4.3 Policy

There are not many governmental instruments identified that could benefit the development and uptake of salt-tolerant potato varieties. However, it is understood that the government does fund certain explorative and developing studies. However, based on the interviews details have not been obtained. What has been identified specifically are the following:

1) €2.120.000,- grant from postcode lottery for Salt Farm Foundation. In 2017 the Dutch Postcode Lottery made a donation to Salt Farm Foundation, intended to fund a multi-annual project in Bangladesh.

2) There is a need for standardization of salt tolerance. *Many* identify the need for an official label, certificate or standardization for salt-tolerance. This is seen as a constraint because it leads to unsubstantiated claims. There is guidance needed concerning labelling salt-tolerance*: "we've been working a so-called 'salt-sensitive passport' that says how salt-sensitive they are. We haven't been able to do that yet because of the variability over the years"* (E2). Thus, there is no official seed-potato yet developed, that could officially be claimed to be salt-tolerant. This poses problems for distribution and retail as well: *"if we* (i.e. trading house) *are asked if we have salt-tolerant varieties, we cannot and will not claim it."* (TH1 endorsed by TH2 and TH3). There are some varieties that perform better under saline conditions that will be recommend in case of demand for salt-tolerance: *"we currently only tell which breeds are best and worst suited for saline soils"* (TH1).

3) Importance of the European Green Deal, SalFar and SALAD project. The European Green Deal is identified by *a few* as a governmental policy that could potentially influence the uptake of saline farming, due to its local character and focus on plant-based food systems. Besides, the SalFar and potentially the SALAD project focussed on exploration of Saline Farming is funded by the European Union. Both are, however, only mentioned by one interviewee.

4) Foreign policies can potentially make exporting difficult. The fact that some countries have import jurisdictions is identified by *multiple* interviewees as a current constraint for the uptake of salt-tolerant seed potato varieties. As E4 argues: *"you cannot just grow any potato anywhere, and certainly not import it"*. E.g. there are numerous countries with breeding lists; *"often salt-tolerant breeds are not listed, making it difficult to cultivate them here"* (E2). It takes time before a product is allowed in a country, specifically when this product is different from common varieties (e.g. purple coloured).

Opportunities	**Constraints**
Postcode lottery +	Need for standardization ---
European Green Deal, SalFar & SALAD +	Breeding lists of foreign countries --

Table 11. *Identified opportunities and constraints from the policy dimension of seed potatoes*

4.4.4 Science

From the interviews a number of knowledge gaps within the scientific field concerning salt-tolerant seed potatoes appeared:

1) Knowledge needs to be updated. *A few* identified that the knowledge is currently not up to date. As WB1 illustrates: "*a lot of knowledge is still based on old figures or outdated experiments. There are no recent norms or standards"*. Therefore, *multiple* identify that currently most research is focussed on requiring new information regarding salt-tolerant seed potato varieties. This needs to be obtained nowadays, as *"in a certain time, could be 20 years from now, salinization will become very important, and then we want to be ready for it. Breeding a potato variety takes about 10 years, so you have to start now"* (TH1 endorsed by TH2 and TH3). However, it is also identified by *many* that in recent years a lot of important research has already been done in this domain, and that progress is made.

2**) There is a knowledge gap identified regarding market research.** *Multiple* identify that the market is a research area that should be examined. There is need for information regarding the end use of salt tolerant potato varieties (e.g. market research and consumer preferences). As a result, there are differing opinions within the sector whether salt-tolerant varieties should be marketed as a special product.

3) Hybrid breeding is identified by *a few* as an opportunity. Also, in this dimension, the faster, and potentially cheaper process of hybrid breeding could aid in accelerating research and development of new varieties.

Opportunities	Constraints
A lot of important research has been done +++	A lot of knowledge is outdated -
Development of hybrid breeding +	Need for market research --

Table 12. *Identified opportunities and constraints from the science dimension of seed potatoes*

4.4.5 Market

For breeders and traders, the revenue is mainly generated by licensing: *"earnings from licences make it possible to investigate salt-tolerant varieties. This is the source of income for our company, and therefore also for the breeding and cultivation of new varieties"* (TH1). Another revenue function of trading houses is the production and distribution, supported by farmers, who get paid through contracted-cultivation.

1) Currently, there is no prosperous export market identified. *Many* endorse that there is not yet an existing export market of salt-tolerant seed potatoes. As E4 argues: *"the moment you have the prospect of large-scale export, you change from pioneer to serious business and can start producing bulk"*. As TH2 explains "*No matter how good a variety performs in the Netherlands, it must also excel abroad"*. Currently, however, the demand from abroad is from developing countries where they have little budget. The need to target more prosperous countries is identified: "*focus on more wealthy European countries where salinization takes place: Spain, Italy and France"* (PM2). The paradox is that *"The value will only increase as the target-area increases, thus as more area becomes saline"* (TH1 endorsed by *a few*).

2) Trading houses have other priorities. Trading houses identified the need to rank the characteristics that future varieties need to obtain. This goes as follows: *"we ask our salespeople once a year what the most important aspects of a new variety are. They come up with a top 10, and salt tolerance is not yet in it"* (TH2 endorsed by TH3). As described in 4.3.2, organic cultivation is for example prioritized over salt-tolerant cultivation.

3) For the Dutch seed potato cultivation volumes are important. When looking at the market dimension, the importance and pride of the Netherlands within the global sector becomes clear. Farmers are highly depended on seed potato cultivation as for many *"seed potato is a cash crop, if the yield and revenue would decrease it would mean end of business"* (SR3). This contradicts with current approaches to sell salt-tolerant seed potatoes to grow into niche products. On Terschelling, e.g., they use salt-tolerant seed potatoes aiming *"to produce products from Terschelling soil, and thus serve restaurants. We don't think about bulk, it's really the small specific market we want to serve"* (F3).

4) There is a need for substantiated marketing measures. After distribution, the retail as well as the processing sector earns revenue out of sales. For the retail sector *"there has to be some kind of marketing involved to market the product as a saline product in a certain segment. You have to try to make a product for which people are willing to pay a higher price, because you will be able to produce less"* (E3), as PM1 adds: *"the market will have to be developed through effective marketing and communication efforts."* Not everybody agrees with the idea to market the product as something special: *"we do not want to commercialise the product as a salty potato"* (TH1 endorsed by *multiple*). Marqt and Jumbo did sell a variety (Miss Mignon) framed as a salt-tolerant potato, however this has no commercial interest as they: "*were sold because the Postcode Lottery made a donation to Salt Farm Foundation. They are also* *shareholder/owner of the Jumbo and Marqt so they wanted to sell them there and give away vouchers for free salty potatoes to members"* (E1).

5) Knowledge exploitation does also pose market opportunities. *A few* identify the exploitation of knowledge as a market opportunity itself. E.g. The Salt Doctors are a consultancy firm selling their expertise concerning salt-tolerant agricultural practices. Governmental representatives are also aware of this opportunity, as *"it is also possible that the profit may solely entail the exploitation of knowledge as this problem is going to increase"* (PM2).

Opportunities	**Constraints**
Licensing salt-tolerant varieties +	Export market does not yet exist ---
Focus on more prosperous countries for export +	Demand from developing countries (little budget) -
Dependency on revenue from seed potatoes as it is the cash crop ++	No priority from trading houses -
Knowledge exploitation +	Need for marketing measures --

Table 13. *Identified opportunities and constraints from the market dimension of seed potatoes*

4.4.6 Culture

Prevailing beliefs regarding the cultural dimension and the symbolic meaning of salt-tolerant seed potatoes became aware from the interviews and are identified in the following paragraph:

1) We are highly dependent on export. When speaking about the cultural dimension concerning (salt-tolerant) potatoes, *multiple* highlight our leading position in the sector, but also our dependency: "*we are dependent on 60-80% export. This has consequences that you see during such a crisis* (i.e. Covid-19), *e.g. the collapse of the global fries' market"* (E1).

2) We are at a crossroad; maintaining our position or changing our system. *Multiple* identify the cultivation of salt-tolerant varieties as means to maintain our leading position within the seed potato sector. Farmers feel likewise and are open to cultivation of salt-tolerant varieties as they identify their current cultivation not sustainable in the long-term and are in need of alternatives. Others argue that overall system change is needed. As TH2 states *"you have to ask yourself; should we* (trading houses) *develop a variety that is more resistant to saline soils, or should people with salinized land start growing other crops?"*

Opportunities	Constraints
Development of salt-tolerant varieties to maintain our position ++	Dependency on export ==
Development of local value chains to become less dependent (and more sustainable) +	

Table 14. *Identified opportunities and constraints from the culture dimension of seed potatoes*

4.4.7 Interim conclusion

In sum, the opportunities and constraints ascending from the various dimensions of the sociotechnical regime of seed potato cultivation are delineated in figure 12. The different dimensions are placed based on the same features as in 4.2.7.

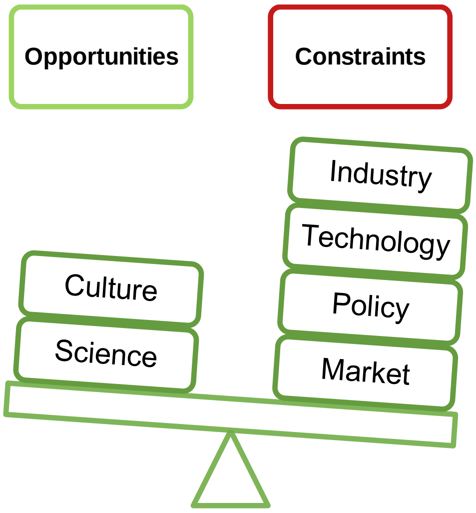

Figure 12. Supporting and obstructing dimensions of the sociotechnical regime of seed potatoes

4.5 Other influences on the scaling of salt-tolerant cultivars

There are certain themes identified that overarch the sociotechnical regimes, but influence the uptake of saline farming as well:

1) A turning point is identified. *A few* identify a change in attitude towards saline agriculture by governmental agents. As E5 states *"At first, policy had the adage 'we must combat salinification'. But now you see people say 'we will prevent it as long as possible, but if it is no longer possible, we will invest in saline agriculture'"*. This results in the new adage of 'mitigation where possible, adaptation where needed'. As E4 explains: "*we strive for mitigative strategies with the aim of maintaining conventional agriculture as it is today. In some places however, it is better to let the saltwater take its course. In those areas, you could potentially apply saline agriculture"*. However, *multiple* identify it also important to remember that saline farming is only suitable for parcels "*where the costs of keeping conventional agriculture sweet outweigh the benefits of saline agriculture"* (E4). IA1 agrees; *"you shouldn't start recommending salt-tolerant crops to farmers unless they can't do otherwise".*

2) There is a need for active, targeted policy in the near future. *Multiple* identify the need for active policy to stimulate salt-tolerant cultivation as adaptative strategy for salinization as well as freshwater shortages. Currently *"there is no active policy to stimulate salinization risk reduction. That's a bit too soon at the moment, because you have to pursue a targeted policy, with targeted strategies"* (E4). PM2 explains*: "active policy isn't on the schedule yet. The ministry prefers it tomorrow, but LTO is holding it back, therefore we have no control over it".* This has consequences, as TH3 explains: "*We start developing faster if there was a subsidy that is very interested in a certain characteristic (salt-tolerant in this case)"* (endorsed by TH1, F1 and F3). In any case, this tardiness is not because of the Minister's personal involvement *"the motivation for her* (Ms. C. Schouten) *to do this is: food security. She really finds it very important. We believe in growing salt-tolerant crops as one of the solutions to the salinization problem"* (PM2). But they cannot do it alone; *"we need Brussel to implement overarching policy at the European level"* (PM2).

3) There are overarching financial instruments. A way in which the government does stimulate research and development of saline farming is through the funding of foreign projects in developing countries, as this supports knowledge exploitation: "*currently we* (i.e. consultancy firm) *have poor clients in developing countries. There is money available to support us, related to development aid. They stimulate this because if they don't, these farmers will come here as immigrants"* (E2). This contributes to the potential revenue model of knowledge exploitation.

4) From a governmental perspective there are subjects were actors are not aligned. A few identify struggles concerning cooperation. As PM2 states; *"certain directives are always a battle, such as the 'water distribution priority sequence'"*. This governmental jurisdiction, however, also plays a role in the potential of saline farming: "*in case of extreme conditions like droughts, this* (i.e. leaching) *is no longer allowed, and we have to think about adaptative strategies"* (WB2). Overall, multiple identify that the cooperation between the agricultural and the governmental sector could be smoothened, as the distance between practice and policy is currently too big. As F6 states: *"the water boards are high and dry"*. The presentation of scenarios by waterboards is identified by a few to be helpful in aiding this problem: "*we need scenarios from the waterboard. Everyone is unsure about what's going to happen, we're not familiar with possible scenarios."* As WB2 explains, this is not needed as they already *"place the responsibility for choosing the right crops with the entrepreneur: 'This is the water you'll receive, it is your responsibility to choose a suitable crop. If you need better fresh water for your crop, then you have to come up with a trick yourself'".* This can be seen as a "*passive invitation*" (WB2) to start salt-tolerant cultivation in areas with salt-containing water supply. Besides, multiple identify also *"a struggle between science and farmers, and therefore it is hard to implement knowledge on the field"* (E1). This may result as scientists need to start executing research in the field instead of in controlled conditions as; *farmers don't benefit from that"* (E1). In total, the cooperation within the agricultural industry "*is very difficult because different parties involved: policymakers, landscape managers, environmental agents, waterboards, soil experts et cetera. They all have an opinion and as a result, few decisions are taken because everyone keeps their hands off the risk as much as possible instead of looking at where to innovate"* (E3).

5) Increasing consciousness will aid in uptake of salt-tolerant products in the consumer market. In the retail sector, it is argued by many that we should look for various ways to expose salt-tolerant products at the consumer market. It seems to be a matter of consciousness: "*we all have the mindset of conventional agriculture; you use fresh water and it grows. You have to think differently to start saline agriculture on a large scale"* (E2). As E1 explains: *"a market of 200-400 million is available. But a number of steps in terms of consciousness have to be taken by (Dutch) society"* (E1). More frequent emerging droughts are expected to increase the level of urgency, because of water stress but also since symptoms of droughts and salt-stress look similar. Besides, the global crisis of Covid-19 is expected to play a role in increasing this consciousness: *"the problem that everything is finite is slowly but surely becoming aware"* (E1). Thus, the need for a different system is identified: *"if different* *countries are supported to link their cultivars directly to water needs, water efficiency and primary protein supply for the local population, then you'll see a difference"* (E1). The more frequent droughts play a role in this as well: "*if it stays as dry, the tipping point of demand may come sooner than you think"* (TH1). F3 agrees: "*people are actively thinking about their dependence on water, I think. Because of such a dry spring, you are conscious about it."* F6 adds: *"if we want to continue with agriculture, we have to take action".* *Multiple* identify that thus it mostly depends on the overarching awareness: *"if we want to do something about salinization it has to be on a larger scale; it has to be general. Then the potatoes or the corn or the quinoa or the sweet potatoes we eat must come from saline agriculture without consumers even knowing"* (E1 endorsed by *many*).

6) There is no direct incentive to switch to salt-tolerant cultivars. *Many* identify that, as long as the waterboards continue to supply water with acceptable effort, there is no direct incentive to switch. This is endorsed by farmers as well as waterboards. As there are currently no warranties regarding the revenue from salt-tolerant varieties, *multiple* experts don't see farmers start cultivating salt-tolerant cultivars quickly.

4.5.1 Interim conclusion

In sum, the opportunities and constraints ascending from overarching themes are delineated in figure 13.

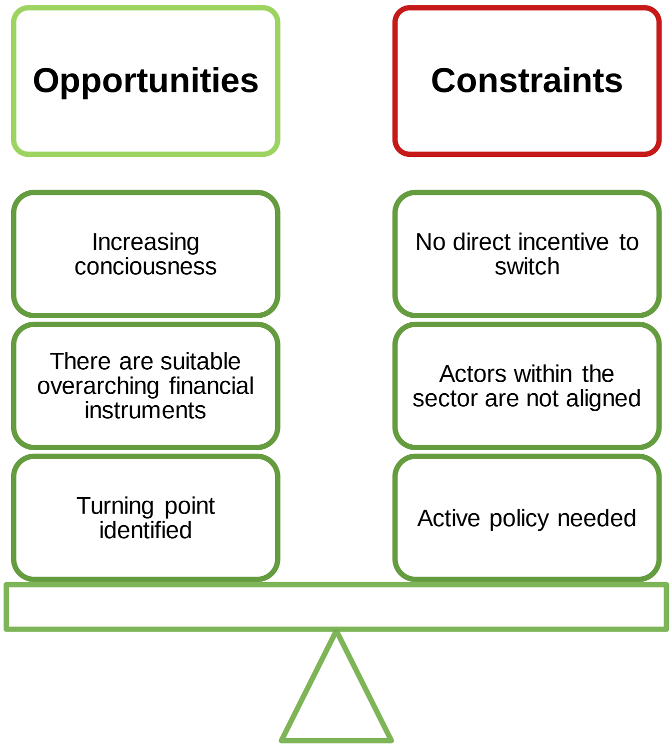

Figure 13. Overarching elements that support or obstruct uptake of salt-tolerant cultivars.

4.6 *What locks in the current sociotechnical regime and what are windows of opportunities for the scaling of salt-tolerant cultivars?*

Window of opportunities and lock-ins which emerged from the interviews are summarized in figure 15[5].

Windows of opportunity	**Lock-ins**
1. Growing awareness due to recent droughts	1. Lacking economic benefits
2. Growing awareness due to Covid-19	2. Lacking awareness and knowledge of salinity threats
3. European Green Deal	3. Desired market: niche vs. common

Table 14. A comprehensive overview of the identified windows of opportunities and lock-ins

4.6.1 Lock ins

Overall, there are certain lock-ins within the landscape that are obstructing the scaling of salt-tolerant seed potatoes identified. The lacking economic benefits to begin with. **Currently, there is no specific market for salt-tolerant products within the Netherlands, let alone for export.** This can be explained because of; 1) no explicit demand for salt-tolerant cultivars from prosperous areas, therefore; 2) no direct priority/urgency for trading houses to develop varieties, therefore; 3) no ability to produce salt-tolerant products in bulk, therefore; 4) no incentive for farmers to cultivate salt-tolerant seed potatoes. Next to the lacking economic benefits, there is also **lacking awareness regarding salinization and the threats it poses**. Thus, there is no awareness of the ability of salt-tolerant cultivars to give economic prospects to marginal land. Therefore, products obtained from saline land currently have no added value on the consumer-market. Moreover, a part of the agricultural sector lacks knowledge and urgency. This is primarily a result of short-term thinking and the prevailing idea of 'mitigation first, adaptation later'. The first is mainly the case for farmers that are unaware of salinization problems and have other priorities. But also, governmental agents and sectoral representatives

[5] *Please note: the sequence is not based on importance.*

see saline farming as a last resort thereby neglecting its possible potential. However, a turning point has been identified as firstly saline farming was a subject not even spoken about in realistic terms. This brings up lock-in three, as **currently the societal demand for saline products stops at the niche market.** The niche market might have benefits for current uptake; however, the question is whether this will aid in scaling. After all, a niche product is not a niche product anymore if it is produced in bulk. Because trading houses are focussed on bulk, they are not interested in producing for the niche market.

4.6.2 Windows of opportunity

Windows of opportunity can occur because developments at the landscape level exert pressure on the existing sociotechnical regime, forcing the regime to open up. When a window of opportunity is developed, a niche innovation has the possibility to break through. The most frequently mentioned (window of) opportunity is following from **the more frequent droughts and the Covid-19 crisis**. Many mention the summer of 2018 as a turning point where farmers and policymakers became increasingly aware of the problems regarding salinization. This led to a growing concern and interest in the subject. Besides, the Covid-19 crisis increased attention to the weaknesses in our current food system and led to an interest in food security-issues. Both can be seen as a shock in the landscape level and lead to increasing awareness regarding dependencies due to diminishing (export) markets. As second biggest agricultural exporter worldwide, it shows our vulnerability. As a result, the interest in a local value chain management is identified to potentially increase. The uptake of salt-tolerant cultivation might benefit from this as Covid-19 could push us in the direction to an overarching system change, where countries consume what they produce.

Another window of opportunity can be found in **our current reputation**. Even though this is not perceived a sudden change, our track-record and expertise in the agricultural sector poses possibilities to focus on the exploitation of knowledge. The Netherlands are one of the frontrunners in the research and development of salt-tolerant varieties. As the salinization problem is expected to grow into a worldwide agricultural challenge, knowledge regarding such an adaptative measure can be of high value. Therefore, next to the export of the products, the export of knowledge should be taken into account. However, in order for that to be beneficial, prosperous countries need to be targeted. Overarching European policies could enhance the research to and development of the cultivation of salt-tolerant varieties.

The European Green Deal could form a window of opportunity as well, as it highlights the importance of some of the benefits of cultivation of salt-tolerant crops. As the European

Commission states on its website: “The coronavirus crisis has underlined the importance of a robust and resilient food system that functions in all circumstances and is capable of ensuring access to a sufficient supply of affordable food for citizens.” Firstly, it stimulates local value chain through the ‘farm to fork’ strategy. Secondly, it introduces “a sustainable food labelling framework that covers the nutritional, climate, environmental and social aspects of food products”. If this label entails e.g. ‘produced on marginal saline soil’ this would take away the struggle regarding labelling within the sector. Besides, the European Green Deal promises to invest €10B in research related to agriculture and natural resources among others. The uptake of salt-tolerant cultivation could benefit from this.

5 Discussion and conclusion

The aim of this research is to examine the viability of saline farming of quinoa and seed potatoes as an adaptative measure to salinization. In order to answer the research question, 32 involved actors have been interviewed. Firstly, the value chain is reconstructed and assessed on evolving opportunities and barriers for the scaling of saline farming of quinoa and seed potatoes. Secondly, the different dimensions involved in the current sociotechnical regimes are identified and delineated, resulting in the identification of opportunities and barriers as well. Lastly, lock-ins that block, and windows of opportunity that support the uptake of innovations are determined.

5.1 Discussion

The obtained results indicate that the lacking economic benefits are the main constraint for the scaling of quinoa and/or seed potatoes cultivation on saline soil. For both products explicit demand misses, and therefore keeping conventional agriculture sweet outweighs the benefits of saline agriculture. The minimal economic prospects could potentially emerge from lacking awareness regarding the salinization issue. Therefore, the uptake of and interest in saline products is currently mainly in the niche market, motivated because of their differentiating characteristics. This niche market, which mainly entails small-scale production with a regional, sustainable image, is expected to continue to develop. However, trading houses are not interested, as they desire a bulk market that is conceivable for products that are cultivated under saline conditions but are not marketed as saline products. Only then, the products will be competitive with similar products from other production systems. Additionally, the opportunity for knowledge exploitation as a business model is mentioned. The Netherlands as pioneer in breeding and propagation of starting material for saline farming will be in line with our reputation and international recognition regarding agricultural innovation. However, conflicting interests of e.g. trading houses versus research institutes delay acceleration, as far-reaching cooperation is uncommon, although identified important. From the perspective of the governmental agents and policy enablers, it has been identified that the adage 'mitigation first, adaptation later' is being followed. This may be changed by the recent droughts, the emergence of Covid-19 into 'mitigation where possible, adaptation where needed'. The mentioned crises and the formulation of the European Green Deal are overall expected to lead to growing awareness and interest in adaptative measures.

When examining all these aspects considering the scaling of saline farming, it is important to acknowledge the belief that sociotechnical regimes are not deliberately shaped. They are the result of different (inter-) dependencies between actors and actions (Geels, 2002a). The acknowledgement that the Netherlands are not common to water-scarcity issues can thus explain the prevailing motto ‘water follows function’, which lead to the identified negative attitude towards adaptation instead of mitigation. As the waterboards manage the demand and supply, this also results in complex power relations; the agricultural sector is dependent on the waterboards, and the waterboards are in turn dependent on the MIWM. However, ministries are in turn pressured by lobby groups. This results in complexities, illustrated by the MNLV that would like to stimulate saline farming, however the water boards don’t see a direct incentive because of affluenct freshwater, and the sector and sectoral representatives obstruct because of the lacking economic benefits. Thus, involved actors are not so much denying or downplaying the possible issues that salinization entails, but rather not experiencing and recognising the situation as urgent enough to change actions. Based on the multi-level perspective there are certain pressures in place that may accelerate this. At the macro-level, there is a growing awareness regarding scarcity, vulnerability and interdependency due to the shocks of the recent droughts and Covid-19. At the micro level, pressure is exerted in the form of further development of knowledge, e.g. more salt-tolerant crops. Up to now, this has mostly been on an experimental or controlled basis in the Netherlands as well as foreign countries. When this adaptive strategy goes through different niches, the market share will grow and even more pressure can be exerted on the existing regime. However, this also brings up the perceived ambiguity of the used multi-level perspective framework of Geels (2002). The different levels described (i.e. niche, sociotechnical regime and landscape) are rather broadly defined. As Berkhout states: “it is unclear how these conceptual levels should be applied empirically.” (2004, p. 54). As such, the indication of saline farming as niche, the sector as sociotechnical regime and societal norms and values are open for debate because of the difficulty to provide clear definitions and boundaries. A recommendation to overcome this ambiguity is to; 1) incorporate a degree of flexibility when utilizing the different levels and especially the sociotechnical regimes; 2) include a clear outlook of the desired sociotechnical regime, and; 3) it is perceived of importance to be transparent in the assumptions made in the methodology as well as in the results.

Within this research, it is interesting to critically reflect on the expected challenges in relation to the expected strategies that were to improve the uptake of saline farming as a viable adaptative measure when facing salinization. It is interesting to make an attempt to link predetermined strategies, newly identified strategies and revealed challenges that will need to be overcome. Figure 14 provides an overview of all strategies and main challenges that came forward.

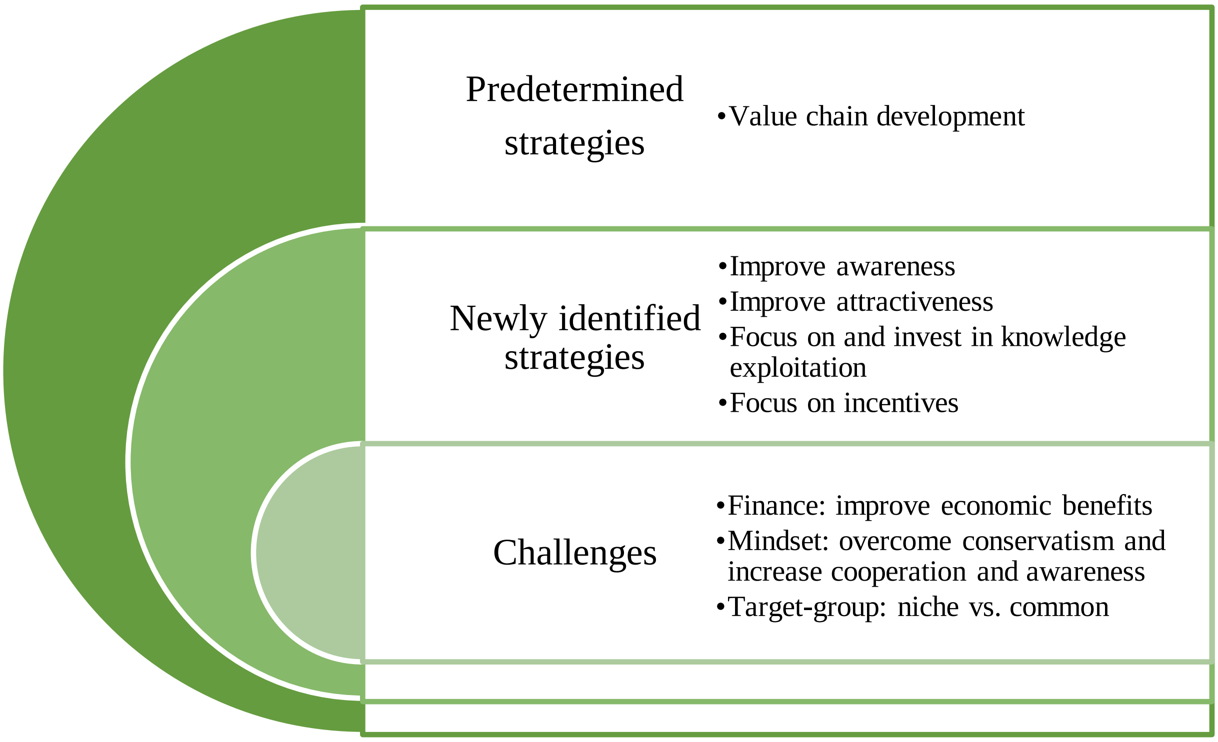

Figure 14. Overview of the identified strategies and challenges.

There are strengths, but also limitations to the findings of this study. First of all, a general strength is the utilization of data triangulation. To answer the research question, multiple data sources were used: interviews, reports, and literature. Additionally, respondents were identified through a snowballing method. This is perceived suitable to generate a representative image of the stakeholders. However, it also brings up the first limitation as a very important group was not open to contribute to the examination; the retail sector. Therefore, the aim to interview all relevant actors within the value chain is not reached, thus the representativeness is affected. This is unfortunate, as they are expected to play a big role in the uptake and thus the economic viability of the products. Besides, their view on the framing of such products (niche vs. common) would be of high relevance. Subsequently, the following limitation is; within this research the perspectives of consumers have not been examined allthough they are end-users within the value chain. Moreover, there have been farmers interviewed, however most are considered pioneers. Furthermore, the sectoral representatives speak for the concerns of their affiliates solely, and not for all farmers. Consequently, the ‘average farmer’ is not represented, which limits the results. Additionally, it is important to mention that the occurrence of Covid-19 made face-to-face interviews rather difficult. Therefore, all but two interviews have been done through Skype or a similar tool. This could be limiting the results, as it was not possible to read facial expressions and indirect responses of interviewees.

Recommendations for further research

This brief overview consists of the most interesting findings and subsequently recommendations for further research:

- Compliance to the market requirements of both products is expected to positively influence the viability of cultivation of quinoa and salt-tolerant seed potatoes as an adaptative measure to salinization. Further market research is needed in order to confirm the identified requirements
- Lacking economic benefits play a big role in the rigidness of uptake of both products. Research within the retail-sector will aid in examination of the potential uptake.
- It is advisable to experiment with different forms of framing of salt-tolerant products such as quinoa and seed-potatoes and focus on market-preferences. This will support the sector as it might smoothen the debate regarding labelling the products as niche or regular product.
- It might be interesting to do a comprehensive research into experienced differences in incentives for various adaptation measures concerning salinization. When different measures and their benefits and constraints will be aligned, this will aid in decision-making processes.
- The later developed “typology of four transition pathways” (Geels, 2007) examine the possibility for transformation to evolve downwards from the sociotechnical regime instead of upwards from the niche level. It could be interesting to focus coming research on whether this is applicable to the transition to saline farming.

5.2 *Conclusion*

This research aims to answer the question: '*Is the saline farming of quinoa and seed potatoes considered a viable option in the Netherlands based upon the opportunities and constraints of the scaling of both products?'* It can be concluded that saline farming is not yet perceived as an economically viable adaptative strategy to salinization. Although there is already relatively much knowledge concerning appropriate production of both products, many of the market requirements occurring from the value chain cannot yet be complied to. Results identify lacking economic benefits as the main issue that obstructs the scaling of saline farming of quinoa and seed potatoes, resulting in lacking development, awareness and urgency within the sector. However, the recent droughts, emergence of Covid-19 and the European Green Deal pose opportunities that may accelerate the uptake of saline farming, as they increase its awareness and benefits regarding local, sustainable food production systems. As the first two are rare external circumstances, they are expected to affect a wide range of actors; from the waterboards to consumers. The latter states to value the various benefits of saline farming and comprises overarching governmental policy that demand compliance.

Most actors currently identify the potential of saline farming either when: 1) its saline origin offers added value, or; 2) when the saline origin of the product does not play a role, but cultivation on saline soil offers added value. The latter is the case when the costs of keeping conventional agriculture sweet outweigh the benefits of saline agriculture. Regardless of its current economic viability, saline farming is perceived as an attractive novel opportunity for e.g. the agricultural sector, water management and landscape development. Therefore it deserves suitable public support for required innovations and transitions. As governments cannot endlessly pursue their efforts to combat salinization in certain areas, the transition from sweet to saline water resources may be required. Governments have the promising opportunity to play an encouraging role instead of a disencouraging one. The mentioned policy recommendations are provided to aid in this process.

Policy recommendations

The most important policy recommendation identified within this research will be presented briefly.

- Farmers are in need of a clearer view concerning the different scenarios that may result from salinization. They want to gain information regarding the various options they currently have, suitable for short-term as well as long-term.

- The non-existing authorization of pesticides for Dutch quinoa cultivation is perceived as a big problem. The easing of this policy could aid in the scaling of quinoa cultivation.
- The sector could use schemes and subsidies that support research and development of salt-tolerant cultivars.
- Both the sector and the public (consumers) have to be educated regarding the problems that salinization potentially entails in order to increase the awareness around the subject itself and the benefits of the utilization of marginal lands with saline farming.
- To conclude: supporting saline farming offers the opportunity to invest in a forward-looking way: instead of buying off damage (e.g. leaching), you can facilitate new production in saline areas thus give marginal land, economic meaning. This will not be economically viable in the short-term, however, when salinization increases at the current rate, maybe its viability will come faster then is expected.

References

Arnold, G., Bos, H., Doef, R., Goud, R., Kielen., N., & Van Luijn, F. (2011). *Water management in the Netherlands.* Rijkswaterstaat, Den Haag, the Netherlands.

Atzori, G., Mancuso, S., & Masi, E. (2019). Seawater potential use in soilless culture: A review. *Scientia horticulturae*, *249*, pp. 199-207.

Avelino, F., & Wittmayer, J. M. (2016). Shifting power relations in sustainability transitions: a multi-actor perspective. *Journal of Environmental Policy & Planning*, *18*(5), pp628-649.

Bazile, D., Jacobsen, S. E., & Verniau, A. (2016). The global expansion of quinoa: trends and limits. *Frontiers in Plant Science*, *7*, 622.

Berkhout, F., Smith, A., & Stirling, A. (2004). Socio-technological regimes and transition contexts. *System innovation and the transition to sustainability: Theory, evidence and policy*, *44*(106), pp. 48-75.

Blom-Zandstra, M. en J. Verhagen, 2015. Potato production systems in diffe- rent agro ecological regions and their relation with climate change. Position paper, Wageningen University & Research , *Business Unit Agro systems Research*, 614, pp. 32.

Blom-Zandstra, M., Wolters, W., Heinen, M., Roest, C. W. J., Smit, A. A. M. F. R., & Smit, A. L. (2014). Perspectives for the growth of salt tolerant cash crops: a case study with potato, 572. Plant Research International, *Business Unit Agrosystems Research*, pp. 36

de Boer, H. C., & Radersma, S. (2011). *Verzilting in Nederland: oorzaken en perspectieven* (No. 531). Wageningen UR Livestock Research.

Brevik, E. C., & Sauer, T. J. (2015). The past, present, and future of soils and human health studies. *Soil*, *1*(1), pp. 35.

Bruning, B. and Rozema, J. (2013) Symbiotic nitrogen fixation in legumes: Perspectives for saline agriculture, in: *Environmental and Experimental Botany*. pp. 134–143

Choukr-allah et al. (2016). “Quinoa for Marginal Environments:Toward Future Food and Nutritional Security in MENA and Central Asia Regions. *Research and Innovation Division, International Center for Biosaline Agriculture*, Dubai, UAE (2-3).

Corwin, D. L., Rhoades, J. D., & Šimůnek, J. (2007). Leaching requirement for soil salinity control: Steady-state versus transient models. *Agricultural Water Management, 90*(3), pp. 165-180.

Daliakopoulos, I.N., Tsanis, I.K., Koutroulis, A., Kourgialas, N.N., Varouchakis, A.E., Karatzas, G.P., Ritsema, C.J. (2016) *The threat of soil salinity: A European scale review. Science of the Total Environment*, 573, pp.727-739

Van Dam, A.M., Clevering, O.A., Voogt, W., Aendekerk, Th.G.L., Van der Maas, M.P., 2007. Leven met Zout Water. Deelrapport: Zouttolerantie van Landbouwgewassen. PPO nr. 3234019400

Dijkema, D.J., Dijk, P.J. Van & Strijker, P. dr. D., 2005. *Evaluatie Uitvoeringsprogramma Innovatie Landbouw Noord-Nederland 2001-2005*

Donovan, J., Franzel, S., Cunha, M., Gyau, A., & Mithöfer, D. (2015). Guides for value chain development: a comparative review. *Journal of Agribusiness in Developing and Emerging Economies 5* (1), pp. 2-23

FAO, 2011. The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO. 2011. The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

Geels, F. W., (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy, 31*(8-9), pp. 1257-1274.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research policy*, *33*(6-7), pp. 897-920.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy, 36(*3), pp. 399-417.

Geels, F. W., (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental innovation and societal transitions, 1*(1), pp. 24-40.

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. *British dental journal*, *204*(6), pp. 291-295.

Herr, M. L. (2007). Local Value Chain Development. *International Labour Organization. Enterprise for Pro-poor Growth (Enter-Growth). Colombo, Sri Lanka*.

Huisman, P., Cramer, W., Van Ee, G., Hooghart, J. C., Salz, H., & Zuidema, F. C. (1998). Water in the Netherlands. *Netherlands Hydrological Society*, Rotterdam.

ICBA (2018a), *Development of Quinoa Based-Products Adapted to Moroccan Context,* International Center for Biosaline Agriculture, P.O. Box: 14660, Dubai, UAE

ICBA (2018b), *Quinoa (Chenopodium quinoa) yield potential in the semi arid region of Rhamna, Morocco under rainfed and irrigated conditions*

Jacobsen, S. E., A. Mujica, et al. (2003). "The Resistance of Quinoa (Chenopodium quinoa Willd.) to Adverse Abiotic Factors." *Food Reviews International 19*(1-2): pp. 99-109.

Jacobsen, S. E. & Sun, Y., (2013). Quinoa: a multipurpose crop with the ability to withstand extreme conditions in the field. *CAB Reviews, 8*(30), pp. 1-10.

Janssens, B., Van den Berg, I., Van Leeuwen, M. & Jukema, N., *Verkenning haalbaarheid glutenvrije keten,* Rapport 2008-034, LEI Wageningen UR, Den Haag, augustus 2008

Jones, A., Panagos, P., Barcelo, S., Bouraoui, F., Bosco, C., Dewitte, O., ... & Jeffery, S. (2012). The state of soil in Europe. *A Contribution of the JRC to the European Environment Agency's Environment State and Outlook Report (European Commission: Luxembourg)*

Jones, E., Qadir, M., van Vliet, M.T.H., Smakhtin, V., Kang, S. (2019) The state of desalination and brine production: A global outlook. *Science of the Total Environment*. 657, pp.1343-1356

Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, F.L. Toth. (2007). *Interrelationships between adaptation and mitigation. Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 745-777.

Lempert, R. J., & Collins, M. T. (2007). Managing the risk of uncertain threshold responses: comparison of robust, optimum, and precautionary approaches. *Risk Analysis: An International Journal*, *27*(4), pp. 1009-1026.

de Louw, P., Essink, G. O., Delsman, J., van Baaren, E. S., America, I., & van Engelen, J. (2019). Het langetermijngeheugen van de zoet-zoutverdeling. *Stromingen: vakblad voor hydrologen*, *25*(1), pp. 43-60.

ter Maat, J., Haasnoot, M., Hunink, J., van der Vat, M. (2014). *Effecten van maatregelen voor de zoetwatervoorziening in Nederland in de 21e eeuw.* Deltares-rapport 1209141-000, Delft, 2014.

Van der Meulen, B., De Wilt, J., & Rutten, H. (2003). Developing futures for agriculture in the Netherlands: a systematic exploration of the strategic value of foresight. *Journal of Forecasting, 22*(2-3), pp. 219-233.

Michel, R., Produccion y exportaciones de quinua, MDRyt, 2012

Ministry of Infrastructure and Water Management (MIWM). (2009a). National water plan 2009-2015.

Ministry of Infrastructure and Water Management (MIWM). (2009b). Wateract.

MLNV, 2020 obtained from on 24-06-2020 https://www.agroberichtenbuitenland.nl/specials/aardappelen/nao

Montanarella, L., 2007. Trends in land degradation in Europe, in: Climate and Land Degradation. Springer, pp. 83–104.

Montanarella, L., Rusco, E. & Toth, G., (2008). Threats to soil quality in Europe. *JRC Scientific and technical reports.* Luxembourg: Office for Official Publications of the European Communities

Nachshon, U., (2018). Cropland soil salinization and associated hydrology: Trends, processes and examples. *Water*, *10*(8), pp. 1030.

Nangia, V., de Fraiture, C., & Turral, H. (2008). Water quality implications of raising crop water productivity. *Agricultural Water Management*, *95*(7), pp. 825-835.

Ondrasek, G., Rengel, Z., & Veres, S. (2011). Soil salinisation and salt stress in crop production. *Abiotic stress in plants-Mechanisms and adaptations*, pp. 171-190.

Oude Essink, G. H. P. (2001) Improving fresh groundwater supply - problems and solutions, in: *Ocean and Coastal Management*, 44, pp. 429–449

Oude Essink, G. H. P., Baaren, E. S. Van and Louw, P. G. B. De (2010) Effects of climate change on coastal groundwater systems : A modeling study in the Netherlands, in: *Water Resources Research*, 46 (October), pp. 1–16

Prins P., Zoetendal J. (2011) “Boeren op weg naar een klimaatbestendige productie”, rapport in het kader van Klimaat en Landbouw (LTO-Noord, Grontmij)

Rengasamy, P. (2006). World salinization with emphasis on Australia. *Journal of experimental botany*, *57*(5), pp. 1017-1023.

Rotmans, J., Kemp, R., van Asselt, M., Geels, F., Verbong, G., & Molendijk, K. (2000). Transities & transitiemanagement: De Casus van een emissiearme energievoorziening. *Maastricht, ICIS, MERIT*, *83*.

Rozemeijer, J., Jansen, S., Villars, N., & Grift, B. V. D. (2017). Mitigation of eutrophication in river basins, lakes, and coastal waters requires and integrated and adaptive approach; experiences from The Netherlands. *AGUFM*, *2017*, H54A-01.

Satijn, H. M. C., & Leenen, J. M. J. (2009). *Leven met zout water: Overzicht huidige kennis omtrent interne verzilting*.

Schaap, B.F. et al., 2013. Participatory design of farm level adaptation to climate risks in an arable region in The Netherlands. *European Journal of Agronomy, 48*, pp. 30–42.

Staveren, G.A. van & Velstra J. (2011*) “Klimaatverandering, toenemende verzilting en landbouw in Noord-Nederland”* Report Acacia Water

Staveren, V. G., & Velstra, J. (2012). *Verzilting van de landbouwgronden in Noord-Nederland in het perspectief van de effecten van de klimaatverandering*. KvR, 58, 12.

Stuyt, L., Snellen, B., Essen E, (2011) “Effecten van aan klimaatsverandering gerelateerde verzilting op de bedrijfsvoering van landbouwbedrijven in Noord-Nederland” rapport Alterra en Aequator.

Stofberg, S. F., Essink, G. H. O., Pauw, P. S., De Louw, P. G., Leijnse, A., & van der Zee, S. E. (2016). Freshwater lens persistence and rootzone salinization hazard under temperate climate. *Water resources management, 31*(2), pp. 689-702.

Stuyt, L. C. P. M., Blom-Zandstra, M., & Kselik, R. A. L. (2016). *Inventarisatie en analyse zouttolerantie van landbouwgewassen op basis van bestaande gegevens* (No. 2739). Wageningen Environmental Research.

Stuyt, L.C.P.M., Kselik, R.A.L., Blom-Zandstra, M., 2016. Nadere Analyse Zoutschade op basis van bestaande gegevens; Inventarisatie van eerder gerapporteerde zouttolerantiedrempels van beregeningswater met ver- hoogd zoutgehalte. *Wageningen University & Research, ESG-rapport 273*9, pp. 157

Van Straten, G., de Vos, A. C., Rozema, J., Bruning, B., & van Bodegom, P. M. (2019). An improved methodology to evaluate crop salt tolerance from field trials. *Agricultural Water Management, 213*, pp. 375-387.

Velstra J., Hoogmoed M., & Groen K. (2009). Inventarisatie maatregelen omtrent interne verzilting. In: Leven met zout water (203). Acacia water.

de Vos, A. C. (2011). *Sustainable exploitation of saline resources. Ecology, ecophysiology and cultivation of potential halophyte crops* (Doctoral dissertation). Vrije Universiteit, Amsterdam, the Netherlands.

de Vos, A., Bruning, B., van Straten, G., Oosterbaan, R., Rozema, J., van Bodegom, P., (2016) *Crop salt tolerance under controlled field conditions in The Netherlands, based on trials conducted at Salt Farm Texel*. Salt Farm Texel

Wicke, B., Smeets, E., Dornburg, V., Vashev, B., Gaiser, T., Turkenburg, W., & Faaij, A. (2011). The global technical and economic potential of bioenergy from salt-affected soils. *Energy & Environmental Science*, *4* (8), pp. 2669-2681.

te Winkel, T., Velstra, J., van Rijselberghe, M., Laansma, K., & van Meijeren, S., (2020) *Zilte kansen Waddenregio.* Acacia water.

Wolkers, J., & Timmer, R. D. (2015). Nederlandse quinoa in de winkel. *WageningenWorld*, (4), pp. 16-17.

Yazar, A., Incekaya, Ç., Sezen, S. M., & Jacobsen, S. E. (2015). Saline water irrigation of quinoa (Chenopodium quinoa) under Mediterranean conditions. *Crop and Pasture Science*, *66*(10), pp. 993-1002.

6 Appendix

6.1 *Appendix 1. List of interviewees.*

Sector	***Seed potatoes***	***Quinoa***	***Coded as***
Trading houses	*C.C. Meijer B.V.*		*TH1*
	HZPC		*TH2*
	Solynta		*TH3*
	Agrico		*TH4*
Farmers	*Texel*		*F1*
		Noord-Holland	*F2*
		Brabant	*F3*
	Groningen	-	*F4*
	Friesland		*F5*
		Flevoland	*F6*
		Zeeland	*F7*
Retail	*Marc.Foods**		*R1*
		Quinoa Holland	*R2*
Policymakers	*Wetterskip Frysland*	-	*PM1*
	Hoogheemraad Rijnland	-	*PM2*
	Ministry of Agriculture, nature and food quality	-	*PM3*
	Wetterskip Frysland	-	*PM4*
Independent agents	*STOWA*	-	*IA1*
	PBL	-	*IA2*
Sectoral representatives	*Boerenverstand*	-	*SR1*
	Royal General Union for Flower bulb culture		*SR2*
	Potato Valley		*SR3*
	LTO-Noord		*SR3*

Experts	*Salt Doctors*	-	*E1*
	ILVO	-	*E2*
	Acacia water	-	*E3*
	Rijksuniversiteit Groningen		*E4*
	ILVO	-	*E5*
	SPNA		*E6*
Quinoa experts		*ICBA*	*QE1*
		The Quinoa Company	*QE2*
		Mercadero	*QE3*
		Wageningen University and Research	*QE4*
		GreenFood50	*QE5*