Saline Food Systems

Reflecting on capacity and knowledge within the Netherlands

Judit Snethlage, Gert-Jan Wilbers& Angel de Miguel-Garcia

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Salinity is becoming one of the larger global challenges for food production and biodiversity worldwide due to climate change and other factors. Many activities are on-going in the Netherlands focused on national and international scale. However, it is unclear what the exact capacity and knowledge on the topic of salinity is in the Netherlands. That is why this report researches what this knowledge and capacity is. The food system approach, interviews are used to identify the knowledge and capacity of the Netherlands in the topic of salinity. The output from the interviews show that there is knowledge and capacity on baseline assessments, preventative and adaptive measures and implementation support. Following from the interviews and literature, recommendations were formed. The recommendations are focused on location specific knowledge, awareness raising & learning, feasibility studies policy embedding and collaborations.

Keywords: Salinity, saline food systems, saline agriculture, food security, salinity and Netherlands

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Executive summary

Salinity is becoming one of the larger global challenges for food production and biodiversity worldwide due to climate change and other factors. The global impact of salinity is far-reaching. It is an international issue threatening, amongst others, sustainable land productivity. Estimates predict that 50% of all arable land will become impacted by salinity by 2050 (Wang et al.,2003). The current global annual cost of salt-induced land degradation in irrigated areas is estimated to be EU € 21.3 billion (US$ 27.3 billion) related to lost crop production (European Commission, 2019). We need, therefore, to adapt farming and food production in these affected areas. As other countries, the Netherlands is experiencing challenges regarding salinity. Salinity is increasing due to sea level rise and intense dry periods are becoming more frequent. Research, both academic and by the private sector, are working on solving these issues. Capacity and knowledge for solutions on salinity are already present or are being developed by different stakeholders. The solutions are supported by governments and by private developers. However, it is unclear what the exact capacity and knowledge on the topic of salinity is present in the Netherlands. To understand the current capacity and asses the knowledge gaps of the Dutch stakeholders coping with salinity challenges, a set of structured interviews were developed, a working session was organized, and 12 stakeholders were interviewed. Combining the interview output with the food system approach, led to the identification of two type of measures for the challenges of salinity; preventative measures and adaptive measures. The interviews also gave insights on the type of capacity and knowledge that could contribute to the measures and solutions. The content of the interviews was mostly focused on the topics of soil, water and crops in the context of salinity. Recommendations followed out of the literature and the interviews. These recommendations are focusing on location specific knowledge, awareness raising & learning, Feasibility studies on preventative and adaptive measures policy embedding & collaborations. The outcomes of the report should become part of developing together international partnerships to streamline diverse efforts in order to optimize investments and maximize results on the topic of saline food systems.

Definitions

Salinity
Salinization is a serious phenomenon widely distributed in various bioclimatic zones of the world, characterised by the increase of salt concentration in soil and water (Vengosh, 2005). The water salinity refers to the amount of salt in the water. This is also called the "salt concentration" and could be expressed in grams of salt per litre of water (grams/litre or g/l) or in milligrams per litre (which is the same as parts per million, p.p.m). The soil salinity refers to the salt concentration in the water extracted from a saturated soil (called saturation extract) (FAO,1994)(FAO,1985).

(bio) Saline agriculture
Developing more climate-resilient, sustainable and innovative farming systems tailormade for the salt-affected areas. It mainly focuses on supporting sustainable food production in increasingly saline environments while contributing to the restoration and/or protection of productive natural capital affected by salinity and water scarcity (FAO,2016).

Saline Food systems
A food system is conceptual description of food value (production) chain and its linkages with socio-economic and environmental drivers. Based on this interconnection it allows to identify food system outcomes from a health diets & nutrition, inclusiveness and resilience & sustainability aspects (van Berkum et al.,2018). Saline food systems refer to those systems affected by salinity as a main driver.

Preventative measures
Measures that are focused on maintaining sufficiently low levels of salinity in soil/water to maintain current agricultural systems as well as removing surplus salts from the system. These measures are aiming on maintaining fresh water related farming and agricultural production systems (based on Green et al., 2016).

Adaptive measures
The term adaptation refers to adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCCC,n.d.) Reflecting on salinity, cases where soil and water salinity reach levels far above current thresholds for irrigation and/or livestock rearing, adaptation is needed to farming and agricultural production systems that function under saline conditions (based on Green et al., 2016).

1 Introduction

With more people inhabiting the earth each day, the demand for food is increasing. Next to the increasing food demand, the climate is changing. The temperatures are rising, and precipitation becomes more uncertain. In the changing climate context, salinity is becoming one of the bigger global challenges for food production worldwide. Also, it is now one of the major causes of biodiversity loss and ecosystem degradation. It is not only affecting food production but also making societies more vulnerable to changes (e.g. uncertain livelihood because of unstable food production). The important role of food production and biodiversity can't be maintained, if structural changes in the food(production) system are not considered. Many areas (e.g. coastal zones, in-land zones) in the world must now deal frequently with soil salinity and brackish water conditions because of different reasons. The global impact of salinity is significant. It is a worldwide issue threatening land productivity, and estimates predict that 50% of all arable land will become impacted by salinity by 2050 (Wang et al.,2003). The current global annual cost of salt-induced land degradation in irrigated areas is estimated to be US$ 27.3 billion related to lost crop production (European Comission,2019) (NL has an income of agriculture of 29.138 million euro per year (CBS,2020)).

Looking to a wider context, saline intrusion is an experience that many countries are facing. Especially, small island states, water-scarce regions with large groundwater abstraction, deltas and other coastal areas. Linking the increase of salinity to a global context and goals, the sustainable development goals (SDG) provide these connections. Considering the topic of salinity interacting with the food system, the most related SDG is number 2 (zero hunger). As salinity affects agricultural production and thus food, the goal and the increasing salinity are linked. Also, salinity reflects and relates directly to SDG 6 (clean water and sanitation). This can be explained as saline water contains high amount of minerals, contributing to a certain (sub)standard quality of the water. Additionally, SDG 15 (Life on Land) has a direct connection with the increase of salinity as it affects biodiversity. In a less direct way it contributes to SDG1 (no poverty) by ensuring a steady agricultural production when a steady saline level is managed, leading to steady agricultural production and thus in providing income poor people.

Private sector and researchers are both working hard to find solutions which can be differentiated between preventive and adaptive measures solutions related to water and soil management to development of salt tolerant crops for fodder and human consumption are just two of a large variety of examples in this context. These are emerging solutions to transform saline challenges into opportunities for both small scale and commercial farmers. We need to build these policies basing them on best practices and lessons learned. It is therefore important that these are documented to ensure we learn from each other and enable up-scaling of these best practices by feeding into policy at appropriate levels. This report is part of building awareness on the capacity and knowledge available in the Netherlands on salinity.

Dutch research organizations and the private sector gained an excellent reputation world-wide on addressing agriculture and water issues. However, at this moment it is not clear what the specific knowledge and capacities are on the salinity topic and what areas of expertise need to be strengthened to answer salinity related questions. It is expected that of some aspects of salinity there is sufficient knowledge present while some topics require additional capacity need development. As such, this report aims specifically at showing what knowledge and capacity is available on salinity in agriculture in The Netherlands and what could be developed for the saline food system.

The report is structured as following, first the research objective and the methods are briefly explained. Followed by the explanation of the relevance. Then the Food System Analysis (FSA) is highlighted and an explanation on salinity is elaborated. After which the FSA is applied to the salinity topic. The salinity-FSA is followed by a part that focuses on capacity of the Netherlands to address NL and international challenges in this field and knowledge gaps appearing. The report ends with recommendations and conclusion.

2 Research objectives

As described in the introduction, the salinity topic is gaining more national and international attention. This is mainly because of the growing need to produce enough food for the people in a sustainable way, taking climate change effects into account. From the increased attention the need developed to have a clear overview on the knowledge and capacity on salinity in the Netherlands. To fulfill the need of creating an overview regarding salinity in a food security context, the following research objectives are formulated:

1. *Give an overview for soil/water management (preventing of salinization and dealing with saline environments).*
2. *Give an overview of which Dutch knowledge and capacity is available on the topic of salinity in the context of (inter)national food security?*

3 Materials and Methods

To fulfill the research objectives as described in chapter 2, the following methods are applied:

Literature review
To present an overview of global (and national) salinity issues at stake, an analysis of the state of the art was developed, based in the assessment of peer reviewed articles, published reports and publication from international organizations (e.g., UN). The list of publication reviewed can be found in the in the reference section. The Food System Approach (FSA) developed by WUR was used to describe the linkage between salinity in agriculture with food systems.

Expert session & Interviews
A starting session has been organized with several experts to kick-start the discussion. This virtually took place on 30th September 2020 with several people listed in Annex 1. This session resulted in input for the presentation on “KennisBasis valuing water” for LNV[1] and a starting point on defining the objectives of this study. Afterwards to get an overview and a starting point on the knowledge and capacity available at the Netherlands, a list was constructed of organizations and experts working in the broad field of salinity and agriculture. This contains research organizations, private sector (including consultancies, specialized companies in water management, financial institutions) as well as governmental agencies to maximize full representation. Also, several experts with Wageningen University and Research are interviewed covering wide-field from salt-resilient crop to water management related applied research. the saline food system. From each category of organization, approximately 2-3 are selected for semi-structured interviews (total of 12 interviews). The full list of organizations and those selected for an interview can be found in Annex 1. Interview guidelines are prepared for each category of organization to identify current activities in the field of salinity and agriculture, knowledge needs and required actions / outlook for the future. These questions can be found in Annex 2.

[1] https://www.wur.nl/en/Research-Results/Onderzoeksprojecten-LNV/Expertisegebieden/Kennisbasis-onderzoek/KB-projecten-lopend-2019-2022/Food-and-water-security.htm

4 The salinity problem: drivers and locations at risk

The salinization problem is a global issue distributed in various bioclimatic zones of the world. Figure 1 shows the regions where soils are affected by salinity from slight to extreme severity (Wang et al., 2019). Currently, only around 3% of all water resources in the world are fresh and that percentage is declining. It is expected that nearly 5 – 10% of all existing freshwater resources will become salinized in the near future (Velmurugan et al., 2019). Thus, generally the share of saline affected soils is expected to increase, and freshwater availability to decrease.

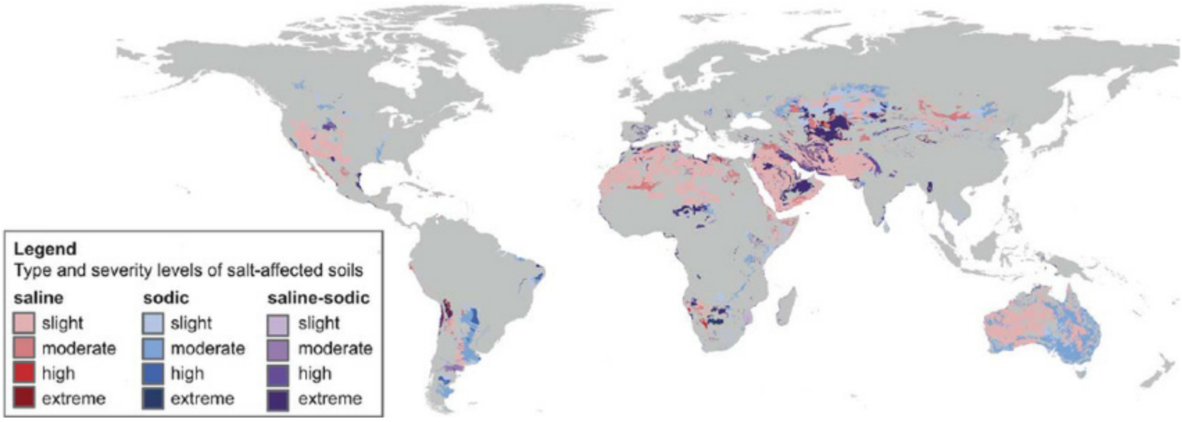

Figure 1 *Soils affected by salinity from slight to extreme levels (Wicke et al.,2011)*

Salinity can be found in different altitudes, from territories below sea level, e.g., the district of the Dead Sea, to mountains rising over 5000 m as the Tibetan Plateau of the Rocky Mountains. The concentrations of salt in water and soil are therefore location specific and may change in time. The salinity is caused by natural and anthropogenic processes the extent of primary (natural) salinization is estimated worldwide to be slightly under 1 billion ha. Secondary (anthropogenic) salinization occurs on around 77 Mha, of which 58% is in irrigated areas. 20% of all irrigated areas is estimated to be salt affected (European Commission, 2019).

Reflecting on different areas and salinization processes, some elaborations can be given as illustrations. For example, climate change results in raising sea-levels which contributes to increased salinity intrusion. This also severely affects the coastal zones and small-island states. These areas are particularly vulnerable to sea-level rise. In arid drylands, the salinization process is driven by erratic rainfall, high evapotranspiration rates and the wide presence of soluble salts (European Commission, 2019). This in combination with excessive groundwater extraction is causing increased water and soil salinization.

Zooming in on another delta area, the Netherlands. It can be stated that the Netherlands also has salinity challenges. Figure 2 shows where the groundwater salinity is located. (shallow) Groundwater salinity is an indicator for soil salinity as well. It shows that the coast provinces and the east are experiencing salinity in the shallow groundwater. Reflecting on the future of salinity in the Netherlands, the salinity levels are expected to rise due to climate change (seawater level intrusion and more erratic rainfall causing dry periods and thus salt built up).

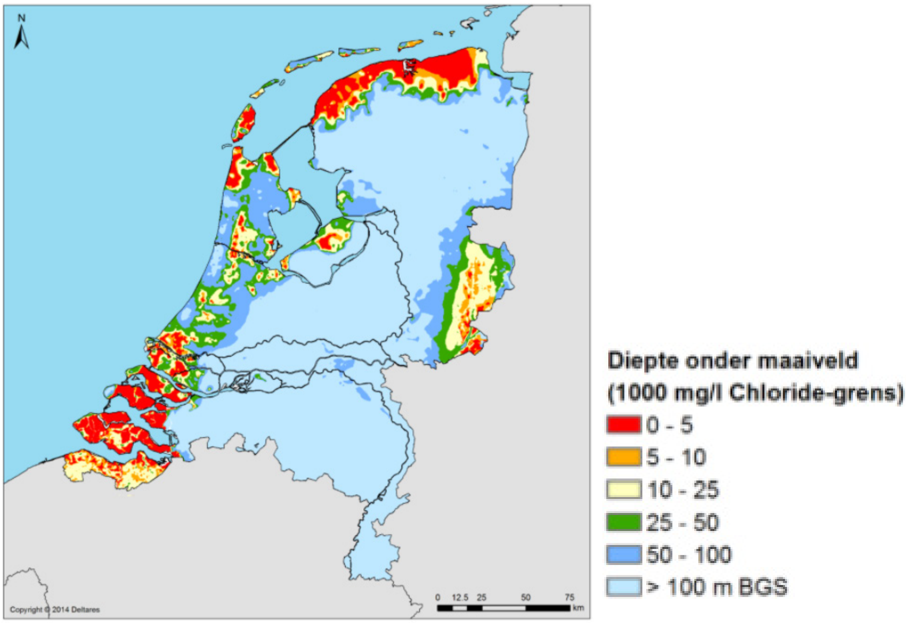

Figure 2 *Salinity groundwater Netherlands (Deltares, 2014).*

It should be noted that due to the non-availability of updated information or lack of compilation of regional level, detailed assessments to the current extent as well as future predictions of salt-affected soils are unknown (Velmurugan et al., 2019). Thus, more research in this field is required (Velmurugan et al.,2020).

5 Effects of salinity on food systems

5.1 Understanding salinity

Salinity intrusion is the upstream movement of brackish or saline water that causes concentrations of salt and other seawater-derived ions to increase above natural background levels (Herbert et al., 2015). This increase can be caused by both anthropogenic and natural processes or a combination of these two. Natural processes can occur in basins with no outlet. The water from the surrounding terrain collects in the basin and the salts it carries becomes concentrated and evaporates. This process leaves salts behind which create saline and sodic soils that are harmful to plants. Salinization can also be anthropogenic induced (secondary salinization) through irrigation that sustains crop production in much of the world's drylands. Here, evaporation of irrigation water carrying dissolved solids may lead to accumulation of salts in the root zone (European Commission, 2019).

These processes are also externally driven, such as global climate change. This is for instance a main driver for salinity intrusion as it causes sea-level rise due to temperature increases and lower river flows as a result of changing rainfall patterns. It is that for this reason that many areas (coastal, (semi)-arid, SID) are under risk of salinity intrusion. Within the context of agriculture, delta regions are specifically vulnerable areas with respect to salinity intrusion due to low-lying lands while being main agricultural/aquacultural production zones. Moreover, coastal agricultural land (such as deltas) and ecosystems account for some of the world's major food production areas, providing livelihoods for coastal communities and contributing significantly to countries' food supply (UNU, 2016). As such, addressing salinity intrusion in these regions is of extreme importance.

Soil and water salinization are also a main issue within tropical and arid regions despite that the processes of occurrence of soil and water salinization are different. An overview of the various processes causing salinity in these regions include (Rengasami, 2006):

- Groundwater associated salinity (GAS) where fluctuation in shallow groundwater levels lead to salt discharge into root zone layers. This process happens particularly in areas with shallow groundwater levels (<4 meters) when natural (deep-rooted) vegetation and agricultural practices disturb the natural equilibrium of water levels causing salt movements to the root zone. Locations where this happens include valleys and foot slopes.
- Non-groundwater associated salinity (NAS) which occurs in regions with deeper groundwater levels (>4 meters). The process is driven by evapotranspiration in combination with insufficient fresh water leaching into the soils which causes accumulation of salts. This may happen in areas where changes in hydrologic situation (e.g. urbanization) reduce the amount of fresh water leaching and may vary from location to location.
- Irrigation associated salinity (IAS) which is due to the input of salts in soils through the application of irrigation water and the accumulation in the root zone. This particularly happens at sites where irrigated land are insufficiently drained. Examples can be found in (semi)arid regions such as the MENA region where pivot irrigated lands became unsuitable for agriculture due to salt accumulation in soils. This can reduce yields by as much as 30%. (European Commission, 2019)

Another form of salinization of aquifers is related to industrial and mining activities that discharge saltwater in surface- and/or groundwater. With respect to mining, the distraction of groundwater may also cause movement of more saline or even brine water from deep groundwater layers towards the upward aquifers.

5.2 Linking Food system Approach and salinity

To understand salinity as a topic connected to the food security, an integral approach is used to reflect on the impact of salinity on the food system in NL and abroad. The incentive to develop a more integral view on achieving food security was a result of increased sharp price rises for agricultural products in 2008/2009. In addition to this, the access to food became increasingly connected to overall food security. These developments took place in a context where the limitations of growth for agricultural became clear, especially taking climate change into account (van Berkum et al.,2018).

This led to the development of an integral approach of the Food System Approach (FSA). Looking more in-depth to the approach several components are visible. There are the drivers, the food system activities and food system outcomes. These are summarized in figure 3. The drivers are socio-economic and environmental. Both drivers have their own interaction with the food system activities as described in Annex 4.

To assess the impact of salinity in a structured way, first the FSA approach is used to reflect on the environmental/agricultural food security. Using this approach in a systematic way, the current knowledge and available capacity concerning salinity knowledge can be assessed. In this way it will become apparent which knowledge/capacity is there and what still needs further elaboration. By researching the drivers and the FSA and incorporating expert knowledge, first insights how salinity is influencing the food system can be reflected on. As a result (displayed in Annex 4), the topic of salinity is now connected to the food system approach, ensuring that the food system drivers (environmental and socio-economic) are related to the salinity. This impact of salinity on the food system drivers and our food system is summarized in figure 4.

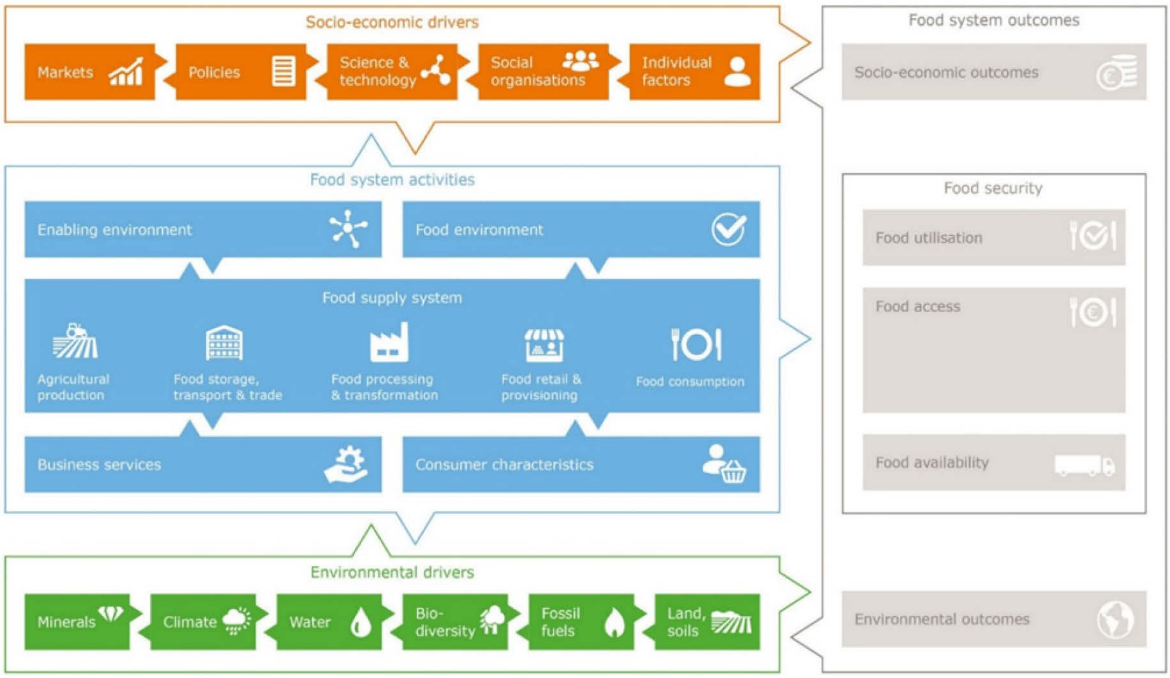

Figure 3 *The Food System Approach (FSA): a way of mapping the relationships of the food system to its drivers (van Berkum et al, 2018).*

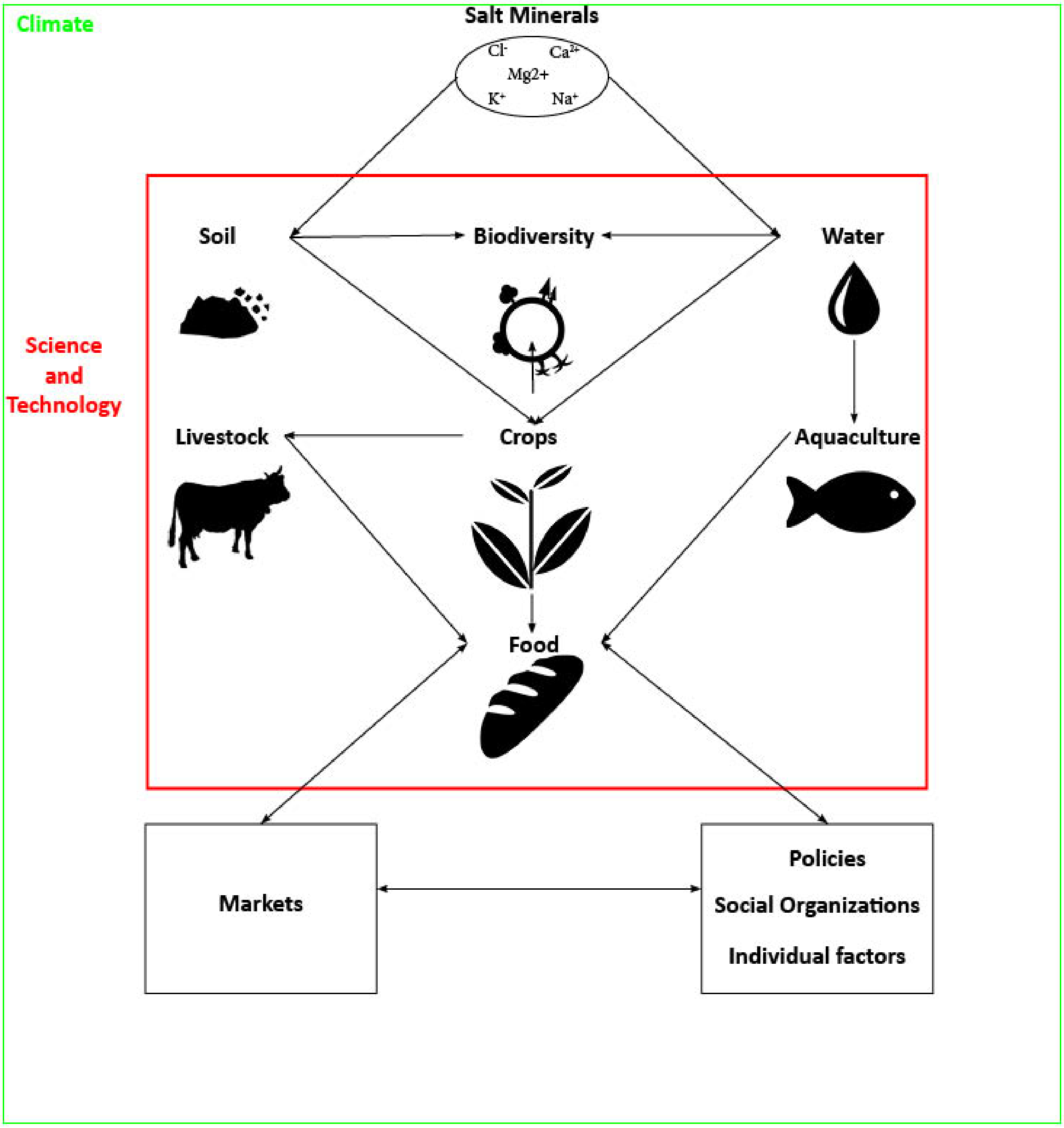

Figure 4 *Impact salinization on FSA factors.*

Elaborating on figure 4, the links between the FSA components and salinity are displayed with arrows. The figure shows the impact of salinity throughout the food system. As can be noticed, some components of the food system are left out of the figure 4. This is done as the food system components are too indirect and do not contribute in a sufficient way of the clarification of the system (such as fossil fuels, see for further elaboration Annex 4). This does not mean they do not have impact at all.

Looking more into detail at the figure (4). One starts at the top with the minerals in the chemical composition. These are the start of salinity and the smallest scale salinity occurs in this system. These minerals are naturally occurring in water and soil and through certain processes (such as geological formations). The minerals are either taken up by the plants through the roots or directly affect biodiversity trough water and soil. The salt minerals then travel from the roots through the crops and get eaten either by animals, humans.

Next to the land component, the water component also has a direct influence as it affects the water quality. The amount of salt directly influences water quality and thus water life. Additionally, there are also "context" drivers. These are the "socio-economic drivers "(Annex 4). These influence salinity in a more indirect, but not less important, way. For elaboration on the explicit relations between salinity and indirect-direct effects on the socio-economic drivers Annex 4 is constructed, including the relevant literature.

Reflecting on the impact of salinity on the drivers one could argue that the socio-economic drivers influencing salinity are less direct links. This is also our conclusion concerning research and within the Netherlands. When researching databases such a google scholar and Scopus, it is clear that less articles on the topic salinity and the socio-economic drivers have been written.

Further reflecting on the interviews, it offers a much more diverse capacity and knowledge on different aspects of the salinity. Still the socio-economic drivers are under highlighted, more specifically policies and markets drivers are under highlighted. These outcomes do not mean that the socio-economic drivers are less important as they influence many aspects, possibly in a less measurable way. The lack of research in this area makes it harder to conclude on the influences these divers explicitly have and to quantify them. In order to clarify the significant influence of salinity on a socio-economic driver, an example has been constructed which can be found in the text box of Annex 4.

5.3 Coping with salinity in agriculture: from prevention to adaptation

As introduced, the FSA is a concept that can be used for looking at the saline food system. Around these topics (such as minerals, markets etc. see table 1 Annex 4), different types of expertise are available or needed.

Irrespective of how salt accumulate in water and soil, it affects plant growth through the osmotic and ionic effects (Munns and Tester, 2008) as it affects the possibility of water uptake by plants (depending per plant and crop type). Moreover, increasing salinity leads to accumulation of ions in the plant causing ion toxicity or ion imbalance (Green et al., 2016). Salinity intrusion can therefore not be ignored, and interventions are required maintain a sustainable agriculture- and aqua cultural production. Based on the literature review and interviews these can be distinguished in roughly two categories: i) preventative measures and ii) adaptation of agricultural systems.

6 Overview expertise needs and capacity

6.1 Salinity related expertise

From the interviews and literature, it was found that knowledge and expertise needs within the scope of salinity are necessary within the fields of

- i) Assessing the current and expected future situation as well as risks of soil and water salinity at multiple scales and regions;

- ii) assessing potential solutions to address salinity issues:

Preventative-related agricultural measures
In order to sustain agriculture practices in (increasing) salt-affected soils, whether in coastal or inland irrigated regions, preventative measures are focused on maintaining sufficiently low levels of salinity in soil/water to maintain current agricultural systems as well as removing surplus salts from the system. Such measures are for instance focused on (re)designing irrigation and drainage management, generation, storage and usage of additional freshwater resources (desalinated water, wastewater, rainwater harvesting) to remove or dilute soil and water salinity. These measures may be combined by selecting more salt resilient crop species. However, accurate and spatially explicit data on soil- and water chemistry is vital, and consideration of the potential effects of differing sources and expressions of salinity is required to make informed assessment of appropriate preventative strategies (Green et al., 2016).

Adaptive measures
In cases where soil and water salinity reach levels far above current thresholds for irrigation and/or livestock rearing, preventative measures may no longer be feasible from cost-beneficial point-of-view. In such events, either coastal or inland regions, the transition of agricultural areas to other (mixed) functions (e.g., saline agriculture, aquaculture such as shrimp farming, hydroponics, treated wastewater) may provide a solution to the salinity problem. Strong salinization is characterized as a non-convertible process. That is why transitional measures should be carefully considered with all the consequences to address salt problems in agricultural systems. In other words, once agricultural systems have salinized to an advanced level it will be very challenging to transfer this back to fresh-water dependent agricultural systems. Interviews further revealed that changing agricultural systems from e.g., wheat and maize production to e.g., saline-related crops (zeekraal, lamsoor) can be very costly and difficult to reverse. Moreover, the business case of saline related crops and aquacultural products are often unsure yet, unknown or not well developed which hampers farmers to take adaptative measures now.

- iii) embedding these actions into plans, strategies and policies.

An overview of the required knowledge and expertise field is presented in figure 5:

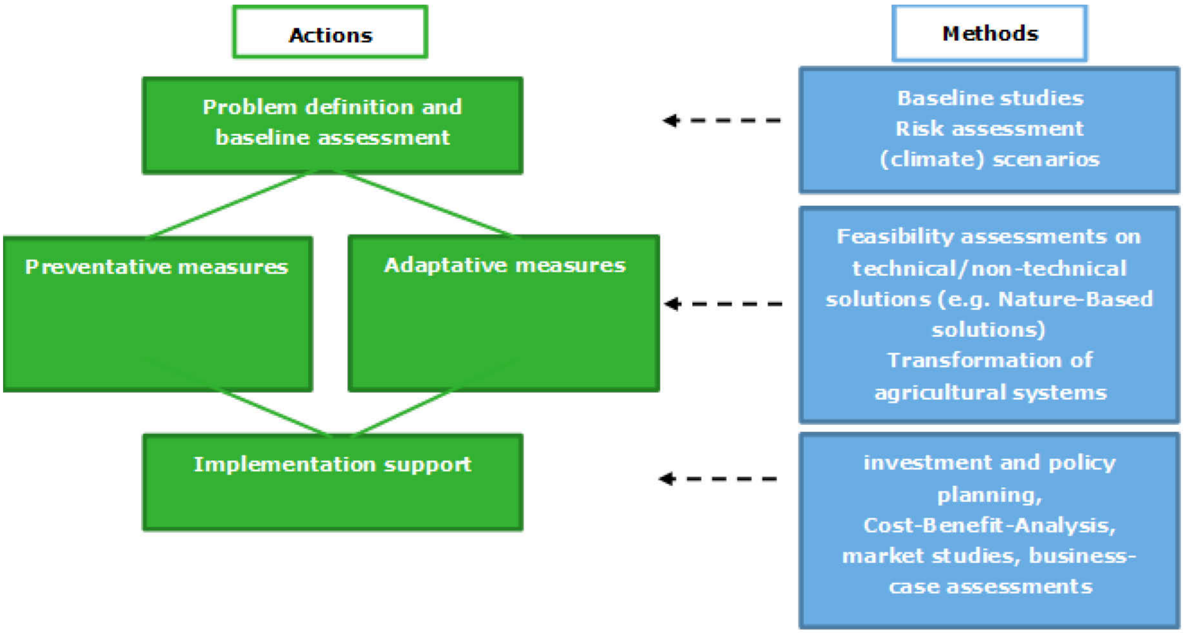

Figure 5 *Overview of actions and examples of methods to address global salinity issues.*

6.2 What the Netherlands can provide

The Netherlands can contribute to the topic of salinization in several ways from problem definition and awareness raising to assess feasibility of preventative and/or adaptive measures and to the support of implementing measures. Table 1a shows the various stakeholder groups in the Netherlands that are active in this field (working in Netherlands and abroad) and what kind of expertise they can bring in, disaggregated to different actions as mentioned in figure 5.

These stakeholders are summarized as the following: Knowledge institutes include public- and private research organizations like universities and private research centers conducting (applied) research. Consultancy firms include advising and consultancy firms that are active in the broad field of the natural environment. Food and feed companies are related to companies producing food and feed products as well as associated inputs. The Service- and technology providers include a broad scope of companies such as on remote sensing, irrigation- and drainage technologies, sensors, hydroponics etc. The financing institutions are represented by banks, insurance companies and governmental organizations are represented by provinces, waterboards, embassies.

Table 1a *Capacity overview of Dutch organizations with respect to identification of salinity issues and baseline assessment.*

Problem definition and baseline assessment	Baseline studies	Risk assessment
Knowledge institutes	X	X
Consultancy firms	X	X
Food and feed companies		
Service – and technology providers		
Financing institutions		
Governmental organizations	X	X

Linking the stakeholders to the capacity needs, the following points can be brought forward; Applied research organizations as well as consultancy firms are widely active in the field of conducting baseline studies and risk assessments related to salinity in agriculture (see Annex 3 for project examples). The broad and unique (inter)national network and expertise fields related to water, agriculture, climate change and salinity are some of the main characteristics of the excellent reputation Dutch knowledge and consultancy firms have both in the Netherlands as abroad. To carry out baseline- and risk assessment studies, Dutch knowledge and consultancy firms often apply include literature review, organizing workshops and interviews with relevant stakeholders (due to broad network), and conducting GIS analyses. In addition, Dutch applied research organization have a broad range of water and agriculture related models and software packages (e.g. SWAP, SWAT) to predict current and future water supply and demand for regions. Nevertheless, these software packages often lack possibilities to predict future water/soil salt concentrations.

Governmental organizations in the Netherlands on the other hand have a wide range of knowledge and data. Waterboards for example periodically assess water quality in catchment areas, including for salinity which can be used for trend analysis and risk assessments. Embassies bring in a broad network of (local) experts as well as knowledge.

Table 1b *Capacity overview of Dutch organization in the field of saline agriculture related preventative and adaptive measures.*

Preventative and adaptative measures	Water/soil management	Feasibility and installation of preventative measures	Salt resilient crops (saline agriculture)	Salt related aquaculture
Knowledge institutes	X	X	X	X
Consultancy firms	X	X	X	X
Food and feed companies			X	X
Service- and technology providers	X	X	X	X
Financing institutions				
Governmental organizations				

Reflecting on the preventative and adaptive measures, The Netherlands also brings in expertise and experience in implementing technologies aimed at preventative and adaptative measures related to salinity in agriculture. On the one hand, Dutch knowledge and consultancy firms have expertise and experience on assessing effectivity of particular agricultural interventions in both fresh and saline agricultural environments and provide training and advice on global level. On the other hand, Dutch drainage and irrigation companies have knowledge, tools and techniques to support implementation of a variety of drainage and irrigation techniques (e.g. drip irrigation) for both fresh and saline conditions (see Annex 1 for list of Dutch companies). In addition, companies focused on water storage and retention are also available in the Netherlands. This is all due to the typical agricultural background of the Netherlands. Moreover, the Netherlands counts multiple service providers such remote sensing-oriented organizations to help in the monitoring effectivity and functioning of agricultural systems and effects of interventions on these systems. This includes translation of data into understandable dashboards for policy makers. Lastly, the Netherlands counts a number of (pioneering) companies, often in close cooperation with knowledge institutes, on producing saline agriculture and aquaculture related products (e.g. saline vegetables and fish as well as more salt resilient crops such as potatoes) as a way to adapt to increasing water and soil salinity.

Table 1c *Capacity overview of Dutch organization in the field implementation support for saline agricultural related interventions and actions.*

Implementation support	Financial-economic analyses	Value-chain and market analyses	Investment planning and policy making
Knowledge institutes	X	X	X
Consultancy firms	X	X	X
Food and feed companies			
Service- and technology providers			
Financing institutions	X	X	
Governmental organizations			X

In order to implement interventions such as the examples mentioned under table 1b, support in the form of market studies, business-case analyses, financial-economic analyses and value chain analyses are required to identify best suitable option. In the Netherlands, knowledge institutes, consultancies as well as financial institutions have expertise in all these fields. Some banks for example carry out market studies to explore current and future risks for farmers and production chains in different regions. However, there is little experience when it comes to these analyses with respect to salinity in agriculture as the topic is perceived as a rather new topic. Similarly, salinity in agriculture may also lead to changes or adjustments in the policies and strategies. Within the southwestern part (Zeeland) of the Netherlands, governments are dealing with this situation and already discussed (or are still discussing) appropriate ways on handling salinity in agriculture. In general, there is still scope to further elaborate on future strategies and policies on handling salinity in agriculture, more elaboration will be explained in the next chapter.

7 Recommendations for further action and identified knowledge gaps

This section is the output of the literature reviews and the interviews. It shows what topics could still elaborated on. Reflecting in a wider sense on the recommendations for further action, there are several levels where the recommendations can be distinguished: on national level (NL), European level (EU), and International level (INT). Generally, it can be said that there are a many initiatives on-going at all levels on the topic of saline food systems. These initiatives need coordination at the appropriate levels. Although a lot is known on salinity topic, there is still much research and development needed. Partnerships between NL and other countries can be beneficial to all parties. This because the Netherlands has a lot of knowledge but does not have all the knowledge. Other countries have different perspectives and environments which can enrich the knowledge base. By combing knowledge and capacity of all levels, we can learn and progress together.

Reflecting on the recommendation topics; The knowledge, capacity and policy needs identified through the interviews and research can be roughly divided into the following categories:

- Location specific conditions of salinity. When reflecting on salinity and food systems be aware that each region is different, and that many aspects influence salinity and its impact on the food produced.
  - Each region (delta, coastal zone, small-island, inland and dry region) need to be assessed separately
  - Environmental aspects (impact of climate change)
  - Socio-economic aspects such as population dynamics related to diet
- Awareness raising & learning
- Feasibility studies on preventative and adaptive measures
- Policy embedment & collaborations

For each recommendation all three levels are relevant (NL,EU,INT). To guide the recommendations, each recommendation is reflected on by highlighting the most relevant levels for that specific recommendation.

7.1 Location specific knowledge

In most areas of the world most (future) issues related to water/salt salinity, particular its effects on agriculture and nature are not well documented/researched. That is why baseline studies in representative areas are strongly suggested by the interviewed stakeholders. These should include regional studies in the Netherlands as well as in Africa, Asia and South America. Some of the topics to be assessed in such baseline studies include *knowledge building and data collection*. Practical examples that can be brought forward are:

- The effects that soil and water salinization can have on market dynamics, policies, employment and poverty alleviation. (NL,**EU,INT**)
- Additional research is needed on the effects of climate change on soil/water salinity. (**NL,EU,INT**)
- the specific effects of various salts and anions on soil biology and chemistry need to be investigated. **(NL,EU,INT**)
- The specific effects of agricultural water management interventions on soil and water salinization in different climatic zones and soils (e.g. moderate, Mediterranean, (semi)arid, tropical regions) need to be researched. (NL,EU**,INT**)
- More accurate and spatially explicit data (measurements) on soil- and water chemistry is vital. The potential effects of differing sources and expressions of salinity is needed to take into consideration in order to make informed assessment of appropriate strategies (e.g. comprehensive mapping and monitoring on global scale). (**NL,EU,INT**)

- Data on saline agriculture, especially in arid countries, is outdated. This data needs to be updated. Moreover, measurements need to be taken in different circumstances (e.g. moderate, Mediterranean, (semi)arid, tropical regions and different type of soils). (NL,**EU,INT**)
- Data collection on intermittent application of salt to (food) crops origins from constant salt application during 1940-1950’s, in arid regions. (**NL,EU,INT**)
- The salt models, from local to global need to improve. Climate change scenarios need to be built into local models in order to improve/develop global salt models. (NL,EU,**INT**)

7.2 Awareness raising & learning

During the interviews and research, it became clear that awareness on the topic of saline food systems is a focus point. The awareness raising concerns developing common understanding and learn together on the topic. This could include, website development, (scientific) publications, news articles, presentations at institutes who are active in the field of saline food systems. Some examples on awareness and learning are being raised in the following points:

- Increase common understanding that salinity levels are varying from non-saline until severe saline, there is no sharp distinction between sweet and salt. Building awareness on the different levels of salinity could support the transition of agricultural systems from preventive to adaptive systems. (**NL,EU,INT**)
- Documentation of lessons learned on the topic of saline food systems should also include the challenges that could not be overcome. Currently the lessons learned are not well documented and/or shared. To learn and move forward, this is a vital point. (**NL,EU,INT**)
- Definition and framing of salinity. When working in the climate smart agriculture and water scarcity area, it becomes clear there is a whole range of definitions for saline food systems. These definitions are used by different stakeholders and in different settings, making it challenging to address the salinity problem. Therefore, defining common definition and understanding would support awareness raising. (NL,**EU,INT**)
- Setting the expectations with saline farming yields. As it is more challenging with saline varieties of regular food crops to produce equal yields as with the normal crops, expectations need to be managed accordingly (e.g. the need for applying efficient soil and water management practices). By assessing the actual baseline situation of the saline agricultural yields, the need for faster developments become more explicit. Making the needs more explicit, the need for technologies, policy and management also becomes clearer. In this way policy can act accordingly. (**NL,EU,INT**)
- Many farmers in developing countries do not attribute the reducing yields to salt. These can be attributed to climate change and/or droughts. Awareness needs to be raised with also at the farmers level that salt can be harmful to plants and therefore result in lower yields. (NL,EU**,INT**)

7.3 Feasibility studies on preventative and adaptive measures

Many technical and non-technical solutions are available to either prevent or adapt to increasing salinization. The application of measures is location specific depending on the regional socio-economic and environmental conditions. However, feasibility studies to assess which measures and interventions should be applied at a certain location are required. More specifically for technical preventative measures, the material- as well as capacity availability should be assessed among economic benefits it may generate. For adaptative solutions, the business cases should be assessed from a value chain perspective/food system approach. This should also include the set-up of pilots, living labs etc. in order to test solutions in the field.

- To adapt to a new situation, a feasibility study is often the first step. A system analysis can support the integral analysis of the feasibility of the situation. This system analysis could be based on the FSA approach. Moreover, it can include value chain analysis and/or potential new business cases. (NL,EU,**INT**)

- As saline farming requires in some cases a switch to a new business case, there is a need for showcasing those business cases. Especially on the topic for adaptative agricultural systems including value chain analyses. When using the African developing markets as example, there is a strong focus on developing poultry sector, seed sector and spices sector. For all sectors the influence of salt has not been extensively researched and the business cases are therefore not convincing yet. Another example of a challenge for the business to incorporate saline farming products such as seaweed in the diet. Where in some regions of the world it is more common to eat seaweed, saline farming products did not enter mainstream in many parts of the world yet. (**NL**,EU,**INT**)
- Working towards integrated saline food systems, circularity is a concept that is also used. This can be implemented within sectors, between sectors and on other levels. An example for the developing markets in Africa that the output from the poultry sector could be used as feed for upcoming aquaculture sector (Tilapia). However, when working closely together between sectors, there is also a risk included. When a component of the system is not functioning accordingly, the whole system will be impacted. This should also be considered when implementing the circular concept into saline food systems. (**NL,EU,INT**)
- Pioneering techniques (such as CRISPR-CAS) are able to contribute to increasing the global food security by gene optimization for e.g. saline environments. These techniques speed up the traditional process of gene editing for agricultural crops. However, the policy of working with such novel techniques, is not widely developed. Therefore, the newest techniques cannot be adjusted yet to produce in an optimal saline environment. (NL,**EU,INT**)
- The current agricultural system has been existing for several centuries focusing on the non-saline agricultural production. The saline agriculture is relatively new agricultural system for some areas of the world and others are dealing with intensifying on the saline environment. The novelty and the change of the level of salinity is a new situation. Therefore, it takes time to move from the experimentation phase to an embedded agricultural system. This shift takes time and needs investments, business cases are challenging to make in this phase of the system. That is why there is a need for time and space to fail. (**NL,EU,INT**)

7.4 Policy embedding & collaborations

Agricultural policies throughout the world are/were particularly focused on maintaining or increasing food production and ensuring food security and safety. Such policies are required to feed populations and maintaining societal stability and prosperity. More recently, increasing attention for sustainable/circular agricultural production arises, particularly within the scope of climate change. However, agricultural policies that are specifically aimed on addressing or mitigating agricultural systems to (increasing) saline conditions are not abundant on all levels. Moreover, the agricultural sector is facing a number of challenges related to meeting future demands for food, fuel, fibre and ecosystem services in a more sustainable manner in the context of a changing climate that still need to be addressed. One of these challenges include the risks of increasing water and soil salinization in agricultural systems and inclusion of measures, interventions and strategies to address those. Some practical focus points are suggested:

- Use the Water, Energy, Food Nexus (WFE) approach to identify how (non)technical adaptative and preventative interventions affect the WFE policy objectives including its synergies and trade-offs. This will help policy makers in defining appropriate strategies and priority settings of investments related salinization. (**NL,EU,INT**)
- Enhance cooperation between knowledge institutes and water-agricultural related private sector. A part of the answer could be in bringing together the knowledge and capacity of all sectors in centers. In this regard some initiatives are already on-going in the Netherlands. These centers bring together several organizations, type of knowledge. Examples are: Rijke Waddenzee program[2], Zoetzoutknooppunt[3] and the Delta knowledge center[4]. (**NL**,EU,INT)

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[2] https://rijkewaddenzee.nl/
[3] https://zoetzoutknooppunt.nl/
[4] https://www.investinzeeland.com/en/news/delta-knowledge-center-provide-boost-zeelands-economy-eu68m-government-funding

- For a saline food system approach, system approach and integration is needed. Therefore, techniques and visions that show these system approach and integration are needed. When working with (pioneer) integration techniques and visions, the supporting policy is challenging. Often the policy support is set within certain boundaries and limits. Being a pioneer, those boundaries can be restricting and find themselves falling between the regulations. (**NL**,EU,INT)
- There is a need for defining regional to national ambitions on the topic of saline food systems in most countries. This ambition could focus on defining local to national strategies to cope with salinity: when to apply preventative- and/or adaptative measures. (**NL**,EU,INT)

8 Conclusions

Soil and water salinity is a world-wide phenomenon which is particularly an issue for SIDS, delta's, including NL, tropical and (semi)arid regions causing severe risks with respect to biodiversity and agricultural production. Improper (agricultural) water management and global climate change are some of the main drivers aggravating the salinity issue and it is expected that 5-10% of all freshwater resources will be salinized in the near future. Within the scope of growing population and associated biodiversity and agricultural commodities demand, this a main area of concern.

Soil and water salinization are however a complex issue depending on various anthropogenic and natural processes. In addition, salinization has a temporal aspect as concentrations in water and soil fluctuate between seasons. As such, research is required to identify the baseline situation of soil and water salinization at regional to local level through assessing both the current- as well as the future situation within the scope of climate change and other (anthropogenic) processes. This baseline assessment is vital, and consideration of the potential effects of differing sources and expressions of salinity is required to make informed assessment of appropriate remediation and/or transitionary strategies to maintain or improve agricultural production within the scope of current and future food demand. Moreover, the critical values of renewable freshwater resources and increasing salinization indicate the necessity for regional water use policy and appropriate water management strategies at various levels.

The Netherlands has extensive expertise in the field of assessing current and future soil and water salinity also within the scope of climate change (baseline assessments) at multiple scales through application of models. Secondly, Netherlands has broad knowledge to identify a large range of both preventative and adaptive measures to address soil and water salinity. Thirdly, Netherlands is experienced in embedding appropriate measures in policies, action plans and investment programmes. Nevertheless, expertise fields in which the Netherlands need to invest in future in order to contribute further in identification and provision of (policy) solutions within the scope of soil and water salinization in NL and abroad include on the topics of Location specific knowledge, Awareness raising & learning, Feasibility studies on preventative and adaptive measures and policy embedment & collaborations.

Reflecting to the wider context again it can be said that policies need to be (further) developed by countries, regional organizations and multilateral organizations. These policies need to be built on evidence from the field in every country. We need to build these policies basing them on science, best practices and lessons learned. We need to feed these practices into policy at appropriate levels. Documentation of these practices is therefore vital. International collaboration and coordination across all relevant entities will be needed in order to learn from each other This report is part of building awareness on the capacity and knowledge in the Netherlands on salinity as part of a puzzle piece concerning the available knowledge.

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Annex 1 List institutes and focus

X = interviewed/ present in startup meeting 30th September

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
Consultancy & engineering consultancy			
Witteveen en Bos	Engineering consultancy also involved in water management	https://www.witteveenbos.com/projects/	
MottMacdonald	Engineering consultancy also involved in irrigation, drainage and water management	https://www.mottmac.com/water-and-wastewater#?nocache=1616668520107	
Larive	Enterprise focus on develop business in high-growth markets including desalinization techniques	https://www.larive.com/larive-acquires-world-leading-water-desalination-technology/	
Resilience	Enterprise focused on building international network organization that carries out research and consultancy projects	https://resiliencebv.com /	
Arcadis	Design & consultancy for natural and built assets	https://www.arcadis.com/nl/nederland/wat-we-doen/onze-capabilities/design-and-consultancy/water-oplossingen/	
The salt doctors	Consultancy & implementation FAO Committee saline agriculture	https://www.thesaltdoctors.com/	X
Nectaerra	Research and consultancy for soil-, surface and hydrogeology and urban hydrology	http://www.nectaerra.com/portfolio/open-field-and-greenhouse-saline-agriculture-and-advanced-water-management/	
Except	Consultancy. Focused on integrated food systems	https://metameta.nl/	X
Future Water	Research and consultancy focusing on practical solutions for water management	http://except.nl/en/	
Acacia	Consultancy. Focus on groundwater	https://www.futurewater.eu/	X
Fresh Studio	Food consultancy	http://www.acaciawater.com/	
Ecofys	consultancy	https://www.freshstudio.nl/	
Delphy	Food and flowers, hybrid form of knowledge and consultancy	https://delphy.nl/en/	
Prins land,water and food consultant	Consultant on water and food.	https://landwaterfood.com/	X

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
Drainage sector (companies)			
Drainagebedrijf Heerschap	drainage sector	https://www.consultancy.eu/country/netherlands	
Drainagebedrijf Rutten	drainage sector	https://heerschapdrainage.nl/	
Drainagebedrijf Barth	drainage sector	https://barthdrainage.nl/	
KnowH2O	Consultancy on hydrology, water quality and water management	https://www.knowh2o.nl/en/	
Drainagebedrijf Combi Drain Assen	drainage sector	https://combidrain.nl/	
Irrigation sector companies			
Broere Hortitech	Irrigation sector	https://aannemers.site/broere-hortitech-bv/24414103	
Tijms	Irrigation sector	http://www.tijms-vof.nl/beregening-3	
Megagroep	Enterpise for a number of wholesale trade companies in spare parts for water transport systems	https://www.megagrouptrade.com/	
Revaho / Netafim	Irrigation sector, importer/wholesaler and producer of a complete product portfolio containing all sort of irrigation products	https://www.netafim.nl/	
Eijekelkamp	Irrigation and drainage sector &sensor companies	https://en.eijkelkamp.com/	
Aquaculture Feed (companies)			
Nutreco/Skretting	Feed (aquaculture) nutritional solutions and services for aquaculture	https://www.skretting.com/	
De Heus	Feed (aquaculture) production and selling	https://www.de-heus.nl/	
Hendrix Voeders	Feed (aquaculture)	http://www.vgnutreco.nl/archief/hendrix-voeders/	
Aquaculture starting material (companies)			
Hendrix Genetics (vis)	Starting material (aquaculture, fish)	https://www.hendrix-genetics.com/en/	
Rijk Zwaan (groenten)	Starting material (aquaculture, fish)	https://www.rijkzwaan.nl/	
Bejo (uien)	Starting material (aquaculture, fish)	https://www.bejo.com/	
KWS (suikerbiet)	Starting material (aquaculture, fish)	https://www.kws.nl/	
East West Seeds	Seed company. Active world-wide	https://www.eastwestseed.com/	
HZPC	Seed company. Active world-wide	https://www.hzpc.com/nl/	X
Meijer / Lamb Weston	Uitgangsmateriaal (aquaculture, fish)	https://lambweston.eu/emea	
Financial institution			
AquaSpark	Financial institute, investment fund in sustainable aquaculture	https://www.aqua-spark.nl/	

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
Rabobank	Financial institute	https://www.rabobank.com/en/about-rabobank/food-agribusiness/index.html	X
Sustainability sector			
ASC	Sustainability	https://www.asc-aqua.org/	
Solidaridad	Sustainability	https://www.solidaridadnetwork.org/	
Remote sensing sector (consultancy/companies)			
VanderSat	remote sensing, provider of global satellite-observed data, products and services over land with a special emphasis on water and crops	https://vandersat.com/	
Nelen en Schuurmans	remote sensing, water management and IT company	https://nelen-schuurmans.nl/en/home/	X
Irriwatch	Irrigation management software	https://www.irriwatch.com/en/	
SarVision	Company remote sensing developing and implementing automated monitoring systems for natural resources management	https://www.sarvision.nl/	
eLeaf	remote sensing, satellite based applications and data to optimise crop production and water management	https://eleaf.com/	
Soil analysis/ research sector (companies)			
Aequator	Soil analysis and research, advisory firm, (re)vitalizing rural areas and interfaces of agriculture, nature, soil, water and land use planning	http://www.aequator.nl/about-us/	
Eurofins Agro	Soil analysis, laboratory and research	https://www.eurofins-agro.com/en	
AgroCares	Soil analysis and research, data solutions to measure nutrients and other key parameters in soil, feed and leaf	https://www.agrocares.com/	
Government sector			
Rijkswaterstaat	part of the Dutch Ministry of Infrastructure and Water Management and responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands	https://www.rijkswaterstaat.nl/english/index.aspx	
Waterschappen	Regional water authorities	https://www.waterschappen.nl/	
Provincie Noord-Holland	Regional government dealing with salinity	https://www.noord-holland.nl/	
Provincie Groningen	Regional government dealing with salinity	https://www.provinciegroningen.nl/	
Provincie Zeeland	Regional government dealing with salinity	https://www.zeeland.nl/	
RVO	Policy support from government for entrepreneurs	https://english.rvo.nl/	X

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
Knowledge institutes			
RUG	Knowledge institute, university	https://www.rug.nl/	
Deltares	Knowledge institute on applied research	https://www.deltares.nl/nl/	
Franeker Academie	Knowledge institute on building knowledge for saline environment	https://www.academiefraneker.nl/	X
Universiteit Utrecht	Knowledge institute, university	https://www.uu.nl/en	
UT Twente	Knowledge institute, university also including water management tracks	https://www.utwente.nl/en/	
Universiteit Delft	Knowledge institute, university also including water management tracks	https://www.tudelft.nl/en/	
Van Hall Larenstein	Knowledge institute applied sciences university, agricultural & water management tracks	https://www.vhluniversity.com/	
IHE Delft	Knowledge institute, also including water management tracks	https://www.un-ihe.org/	
HAS (hoge agrarische school)	Knowledge institute applied sciences university	https://www.hasuniversity.nl/	
Hoge school zeeland	Knowledge institute applied sciences university, aquaculture, delta knowledge	https://hz.nl/en/	X
Salt Farm Foundation	Foundation saline agriculture on field scale level	https://saltfarmfoundation.com /	
SPNA	Knowledge institute focus on saline tolerant agricultural plant varieties and impact on soil	https://www.spna.nl/	
Platforms			
Programma Rijke Waddenzee	Knowledge center on bringing together integral approach on saline environments	https://rijkewaddenzee.nl/	
Zoet zout knooppunt	Knowledge center collecting knowledge on saline environments	https://zoetzoutknooppunt.nl/	X
Deltaplatform	Knowledge center collecting knowledge on the Delta	https://www.deltaplatform.nl/	
STOWA	Knowledge center on bringing together knowledge from regional water management in the Netherlands	https://www.stowa.nl/	
Other institutions dealing with saline topics		https://www.thepotatovalley.nl /	
Potatoe Valley	Research on potatoes	https://www.thepotatovalley.nl/	
ICCO/Cordaid	NGO on cocoa, also involved in salinity projects	https://www.icco-cooperation.org/en/	
LTO Noord	Farmers collective also dealing with salinity challenges	https://www.ltonoord.nl/	
It Fryske Gea	Collective on nature protection of Friesland	https://www.itfryskegea.nl/	
Metameta	Social enterprise focus on practical solutions for better land and water management and to introduce these at scale		

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
Remon	Drilling for water, water treatment	https://www.remon.com/	
Netherlands African Business council	Organization for trade and investment facilitation for Africa in the Netherlands, focusing on salinity as topic	https://nabc.nl/	X
SOWATR	Farming method for large-scale commercial production	https://sowatr.com/	
NoordOogst Aquaponics	Innovative aquaponics technology for working with saline water	https://noordoogst.nl/aquaponics/	X
Saline producers/products			
Zeewaar (zeewier boederij)	Seaweed farm	https://www.zeewaar.nl/nl/	
Teler zeegroentes	Grower of sea vegetables		
Elenbaas Zeegroenten	Grower of sea vegetables	http://www.zeekraal.nl/	
visteelt op land (Wieringermeer, Texel) meromer	Aquaculture on land		
visteelt op land (Kamperland) (Seafarm)		https://www.seafarm.nl/	
Zilte Smaak Terschelling	Saline culinary products	https://www.deziltesmaak.nl/	
Marc Foods	Saline culinary products	http://www.marcfoods.nl/	
Zeeuws Zilt (culinaire producten)	Saline culinary products	https://www.zeeuwszilt.com/	
Noordzeeboederij	Seaweed farm foundation with broad impact	https://www.afas.foundation/portal-afas-foundation-project/noordzeeboerderij	
WUR			
WUR: WENR team: Water and Food	Many years' experience in MENA with salt water, Bangladesh, Myanmar & Vietnam salt (water) management, water-reuse an soil experts	https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Programmes/Sustainable-Water-Management/Water-and-agriculture.htm	X
WUR: WENR team: Bodem, water en Landgebruik	Modelling with saline environments with SWAP-WOFOST, soil scientists focused on salinity. Soil scientist focussed on salinity	https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Programmes/Sustainable-Water-Management/Water-and-agriculture.htm	X
WUR: Wageningen Plant Research, team: agrosysteemkunde	Integrated systems	https://www.wur.nl/en/Research-Results/Research-Institutes/plant-research.htm	X

Institute	Category & Notes	Links	Interviewed/present in startup meeting 30th September
WUR: Leerstoelgroep WRM (water Resource Management)	Water management, irrigation and drainage under saline environments	https://www.wur.nl/en/Research-Results/Chair-groups/Environmental-Sciences/Water-Resources-Management.htm	X
WUR: Leerstoelgroep SLM (Soil Land Management)	Ecohydrology	https://www.wur.nl/en/Research-Results/Chair-groups/Environmental-Sciences/Soil-Physics-and-Land-Management-Group.htm	X
WUR: WFBR: Wageningen Food &Biobased Research team: BBP Bioconversion	Water technology for desalinsation	https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/food-biobased-research.htm	X
WUR: Plantenwetenschappen (Labaratorium voor Plantwetenschappen)	Salinity-plant interactions, lab testing and yield responses	https://www.wur.nl/nl/Onderzoek-Resultaten/Leerstoelgroepen/Plantenwetenschappen/Laboratorium-voor-Plantenveredeling-1.htm	X
WUR: Cooperate	Director of the Food Security and Valuing Water Program	https://www.wur.nl/en/Research-Results/Onderzoeksprojecten-LNV/Expertisegebieden/Kennisbasis-onderzoek/KB-projecten-lopend-2019-2022/Food-and-water-security.htm	X

Annex 2 Questions interviews

Interview guideline
Salinity intrusion is an increasing world-wide problem caused by a mix of anthropogenic and natural processes. The Ministry of Agriculture of the Netherlands (LNV) approached Wageningen Environmental Research to conduct a study on assessing which stakeholders in the Netherlands are working on this issue and what kind of activities are ongoing and/or planned in the near future. In this context, we would like to interview Dutch organizations within the fields of research institutes, engineering firms, water and food related companies, financial institutions and governmental organizations. The interview guideline presents the main questions.

Research Organizations and engineering firms

Current activities in the field of salinity intrusion and agriculture
- What kind of services do you provide in this field?
- What are the main questions related to salinity and agriculture you are working on?
- Do you have ongoing or planned projects in this field?
  - Could you share the main content
  - Objective of the study
  - Client
- Do you see trends in the kind of questions you receive from the market with respect to salinity and agriculture?

Knowledge needs
- Is your organization experiencing knowledge gaps to address salinity-related questions? If yes, which ones and how are you planning to address those?
- Do you think salinity intrusion provides opportunities for your business? If yes, could you please specify?
- With which organization would you expect cooperation on this issue and how would you foresee this cooperation in practice?

Main problems and risks of salinity and agriculture in general
- What do you think are the root causes of soil and water salinity and how do you expect to evolve this in the future?
- Who are suffering most from increasing soil and water salinity?
- What are the main solutions to address those?
- In which areas in the world (geographical location and zones such as coastal zones, inland areas) do you see most work in this field?

Water and food related companies

Current activities in the field of salinity intrusion and agriculture
- What kind of services and/or products does your organization provide?
- How does world-wide saline intrusion in the agricultural sector affects your business?
- Could you provide examples of risks or opportunities it generates for your business?

Knowledge needs
- Is your organization in need for acquiring knowledge and/or expertise in the field of increasing salinity and agriculture?
- With which organization(s) would you expect cooperation on this issue and how would you foresee this cooperation in practice?

Main problems and risks of salinity and agriculture in general
- What do you think are the root causes of soil and water salinity and how do you expect to evolve this in the future?
- What are the main solutions to address those?
- In which areas in the world (geographical location and zones such as coastal zones, inland areas) do you see most work in this field?

Financial institutions

Current activities in the field of salinity intrusion and agriculture
- To what extend is increasing salinity in the agricultural sector on the agenda for your organization?
- Do you think salinity intrusion cause risks for certain businesses? If yes, could you specify which risks and for which sectors?
- Do you also see or experience opportunities in this field for businesses? If yes, could you specify for which sectors and what kind of opportunities that may be?
- Is salinity in agriculture factored-in when judging a request for financing business initiatives?

Knowledge needs
- Is your organization in need for acquiring knowledge and/or expertise in the field of increasing salinity and agriculture?
- With which organization(s) would you expect cooperation on this issue and how would you foresee this cooperation in practice?

Governmental organizations

Current activities in the field of salinity intrusion and agriculture
- What are the main questions related to salinity and agriculture your organization is dealing with (if any)?
- Do you have ongoing or planned projects or programmes you want to carry out in this field?
  - Could you share the main content
  - Objectives of the projects/programmes

Knowledge needs
- What kind of knowledge is your organization looking for when talking about the subject of salinity and agriculture?
- With which organization would you expect cooperation on this issue and how would you foresee this cooperation in practice?
- Do you think salinity intrusion also provides opportunities for your business? If yes, could you please specify for who?

Outlook to the future
- Which sectors will be most affected by salinity intrusion?
- How high is this issue on your organization’s agenda compared to other environmental issues?

Annex 3 Project Examples

Example: Deltas Under Pressure (Bangladesch & Vietnam)

https://www.wur.nl/nl/Publicatie-details.htm?publicationId=publication-way-353630313930
Delta regions are strong contributors to food production and other environmental services. However, they are also particularly vulnerable to the effects of climate change. Typical stresses for Deltas are: Sea level rise, floods, drought, salinity, acidity, humidity, waterlogging, subsidence, pest and other diseases (exacerbated by above abiotic stresses).

Availability of fresh water of sufficient quality and maximization of the use of salinizing regions (and flood protection) are the essential components of food systems in Deltas. Changes are happening rapidly and in a complex setting – it is difficult to foresee what a sustainable transition pathway could look like. The research program explores what is needed for viable and feasible transition pathways for the food system in deltas under pressure. It works in 2 case studies: one in Bangladesh and one in Vietnam. Specific attention is given to the influence of salinity in the food system, now and in the future.

Example: STOP

https://library.wur.nl/WebQuery/wurpubs/fulltext/315166
Many areas in the world must deal frequently with soil salinity and brackish water conditions because of different reasons. Due to these problems' food self-sufficiency is at stake in many of these countries. Potato is the champion staple crop with a high nutritional value and a low water footprint. The pilot project reported had as main objective to select salt tolerant potato cultivars in order to make brackish waters available for food production.

Some results include that (i) several potato varieties were found to perform well, for irrigating with water of a salinity up to 5 dS/m. Adequate water and crop management are a pre-requisite for this; (ii) soil moisture monitoring has been extended with monitoring of soil salinity and sensors proved to be important tools to extend knowledge. Placement of sensors in combination with nonuniform water application is not easy; (v) soil moisture monitoring has been extended with monitoring of soil salinity and sensors proved to be important tools to extend knowledge of soil conditions.

Examples: Joint Cooperation Program Bangladesh &Egypt

https://www.wur.nl/en/project/JCP-Joint-Cooperation-Programme-Bangladesh-the-Netherlands.htm
The Joint Cooperation Program Bangladesh is a multi-year program between Bangladesh and the Netherlands is aimed at sharing and developing knowledge in the field of water management. Under this program several activities are being undertaken regarding salinization. The highlighted activities here are the quantification of salinization on field-level and on nation-wide level with modelling (SWAP-WOFOST for field scale and Bangladesh Metamodel for nationwide scale) and capacity building with local stakeholders for working with the quantification on modelling. With these models there can be calculated, for instance, how much damage a certain level of salinity is inflicted to rice crops. The capacity building is done by experts who have several years' experience in giving training in real life and online. This led to an increased understanding of salinization levels on different scales.

Looking at the Egypt Joint Cooperation Program, a situation can be summarized as that the Northern Nile Delta is under pressure by the combination of sea level rise and water supply reductions due to upstream (both within Egypt as well as in other countries) developments. This will result in both increasing irrigation water salinities and higher soil salinities demanding new agricultural systems to provide the 4 million farmers affected with an income. The problem faced is the uncertainty about the effects of SLR and upstream developments on the extent ad level of salinity increase expected.

For a number of scenarios on sea level rise and upstream water supply developments we will predict a range of effects on irrigation water salinity and agriculture. This will be done through a modelling exercise (SEAWAT/SIWARE) and stakeholder consultation.

Example water and food services

https://landwaterfood.com/research/water (Vietnam)
An increased sea level and coastal inundations cause salinization of agricultural land in the deltas. Salt and agriculture tolerate each other poorly. All sorts of solutions are conceivable. For example, an improved protection of coastal areas to supplying fresh water. Recent projects show that even in coastal areas, fresh water in the soil can be buffered in freshwater lenses and aquifers. Other applied research made clear that some crops and varieties have a certain salt tolerance. Together with Wageningen University and Research (Plant Research) a mission was carried out to the Mekong delta to identity crops which could be suitable for saline soil conditions. The Flora on Salt and Drought Tolerant Crops was published October 2017. Viet Nam Farmers' Union and East West Seeds were also involved in this project.

Example project integral saline products Zeeuwse Tong

https://www.visserijnieuws.nl/nieuws/proefproject-zeeuwse-tong-beeindigd
https://hz.nl/opleidingen/zeeuwse-tong (NL)
Since mid-2009, research has been carried out within the Zeeuwse Tong project to cultivate fish, ragworms, shellfish and saline crops in a closed cycle. The aim of the project is to transform the pond cultivation of seafood within the dike into a new economic sector in Zeeland. Within a pilot farm, sole is cultivated in combination with ragworms, shellfish and saline crops. The knowledge that has been developed in the field of controlled production of ragworms & sole, algae & shellfish and saline crops is elaborated in business plans. The ideal envisioned by the Zeeuwse Tong Foundation is a mixed saline company: a new type of agricultural company that combines different vegetable and animal crops in a saline environment into one robust, closed production system. With ragworms that are produced as food for sole, fertilizers for fish and ragworms, which stimulate vegetable production in the form of algae and saline crops, which in turn are the food for shellfish and ragworms.

Example project climate smart farming: RECSA

http://csa-bangladesh.org/ (Bangladesh)
Research and education is the first step in adapting the agricultural system to climate change. That is exactly where Project RECSA: Climate Smart Agriculture for a Resilient Coastal Bangladesh comes in. Our mission is to support Patuakhali Science and Technology University (PSTU) to set up the department of Climate Smart Agriculture. This department will constitute a research institute and a master program. The focus of this institute is not only on gaining knowledge, but also on sharing knowledge. Implying that researches will often be conducted in close collaboration with local organizations, communities and farmers.

Example saline farming techniques: aquaponics

https://noordoogst.nl/aquaponics/ (NL)
Aquaponics is a mini cycle of aquatic animals, bacteria and plants that provides food. Fish are fed and provide the nutrition for vegetables. It is sustainable because it saves on food miles, it can be done completely without antibiotics and pesticides. Moreover, it is economical with water because it takes place in a closed system where the naturally occurring bacteria together with the plants purify the water.

There are several techniques in circulation:

Ebb and flow system, where a growth bed filled with a medium such as gravel or hydro grains fills and empties automatically. The water is collected in the fish tank or in a buffer that pumps it back to the fish tank.

Floating bed system. The plants float or hang in the water. This can be directly above the fish tank or in a separate basin.

Nutrient Film Technique. This technique comes from hydroponics. It works with pipes or gutters in which the plants are placed and through which a thin layer of (film) water runs continuously. The water from the fish tank is first coarsely filtered to prevent clogging. This technique is particularly suitable for vertical farming or when little surface area is available.

Example Financial institution

https://www.rabobank.com/en/about-rabobank/innovation/food-and-innovation/index.html
Global Farmers is a worldwide digital platform for Rabobank’s agricultural clients. The platform offers farmers around the world access to knowledge and networks that can help them lead a more successful agricultural company. Thousands of Rabobank farmer clients have easy access to each other and Rabobank’s extensive knowledge base, with information, research and direct contact with Rabobank colleagues in this exclusive community that shares farming knowledge, exchanges ideas and extends networks from all around the world.

Example saline irrigation water project Agrimar (Bangladesh)

https://en.acaciawater.com/nw-29143-7-3728798/nieuws/agrimar_bangladesh.html?page=1
In large parts of Bangladesh’s rural coastal region the population has limited access to safe drinking water due to salinity in both shallow and deep groundwater. During the dry season, many of the delta’s rivers and canals turn saline. The abundant monsoon rains provide large amounts of freshwater and applying ASR has proven to be a suitable solution for bridging the water availability-demand gap: available freshwater from the rainy season can be stored in brackish aquifers to be used during the dry season. The rainwater is captured in ponds, filtered, and pumped into a surface reservoir from where it can infiltrate into the aquifer via one or multiple recharge wells. The water is stored in the underground, safe from contamination and evaporation. During the dry season, when the demand is high, it can be pumped to the surface.

Infiltration water is collected in a pond, pre-filtered in a sand filter and infiltrated in the shallow confined sand aquifer via four to six infiltration wells that are placed around a central abstraction well. The drinking water MAR systems have provided important knowledge on the technical functioning and – more importantly – on the socio-economic sustainability of MAR systems in the coastal zone of Bangladesh. Drawing on the experience of implementing the drinking water MAR systems, the concept was adapted for irrigation water.

At the pilot site, rainwater is collected in shallow ponds. The AgriMAR system shows great potential for improving off-season irrigation agriculture in Bangladesh by allowing for an extra harvest of high-value crops during the dry season.

Annex 4 Food system & salinity elaboration

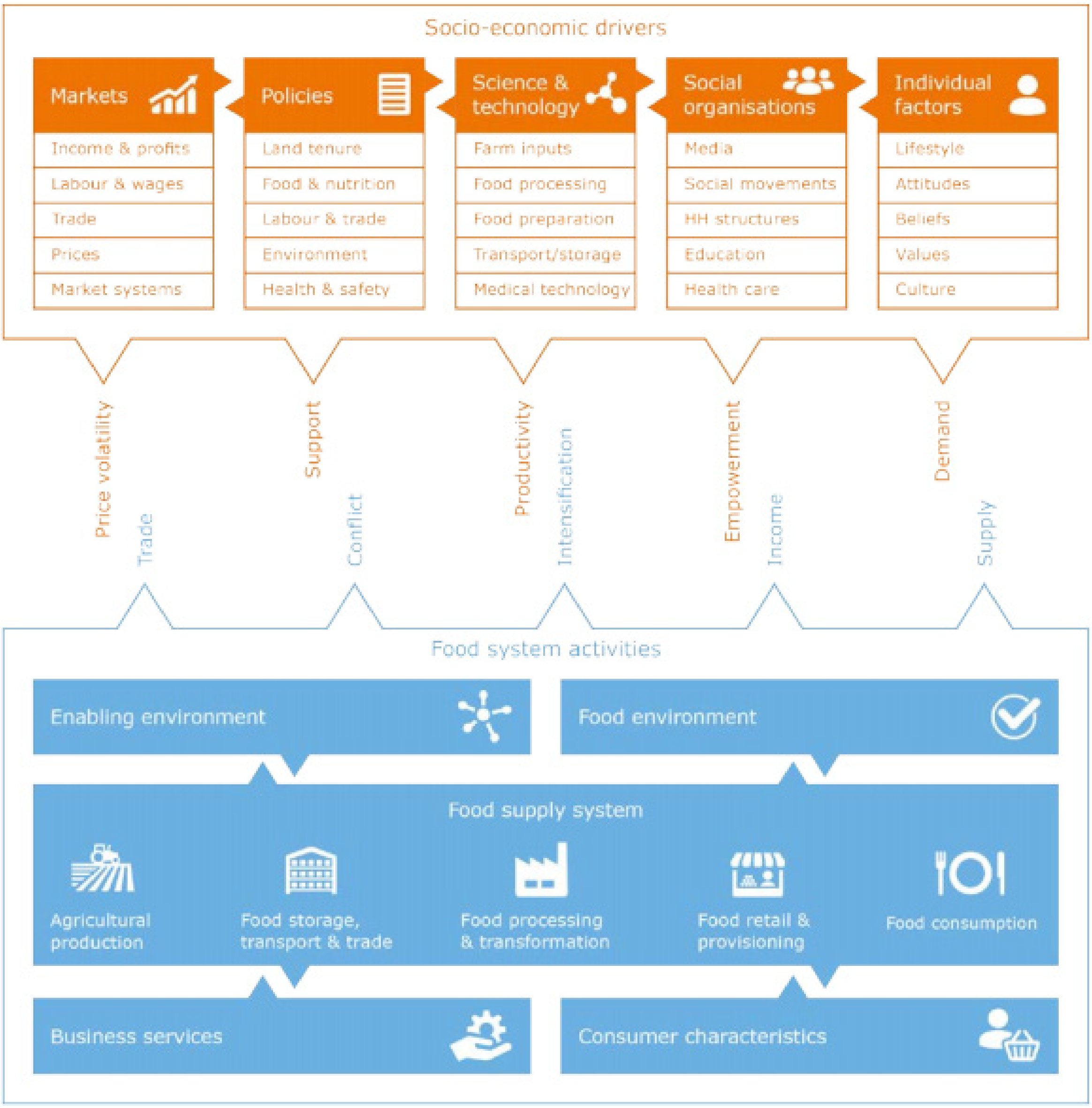

Figure 6 *Socio-economic drivers FSA (van Berkum et al.,2018).*

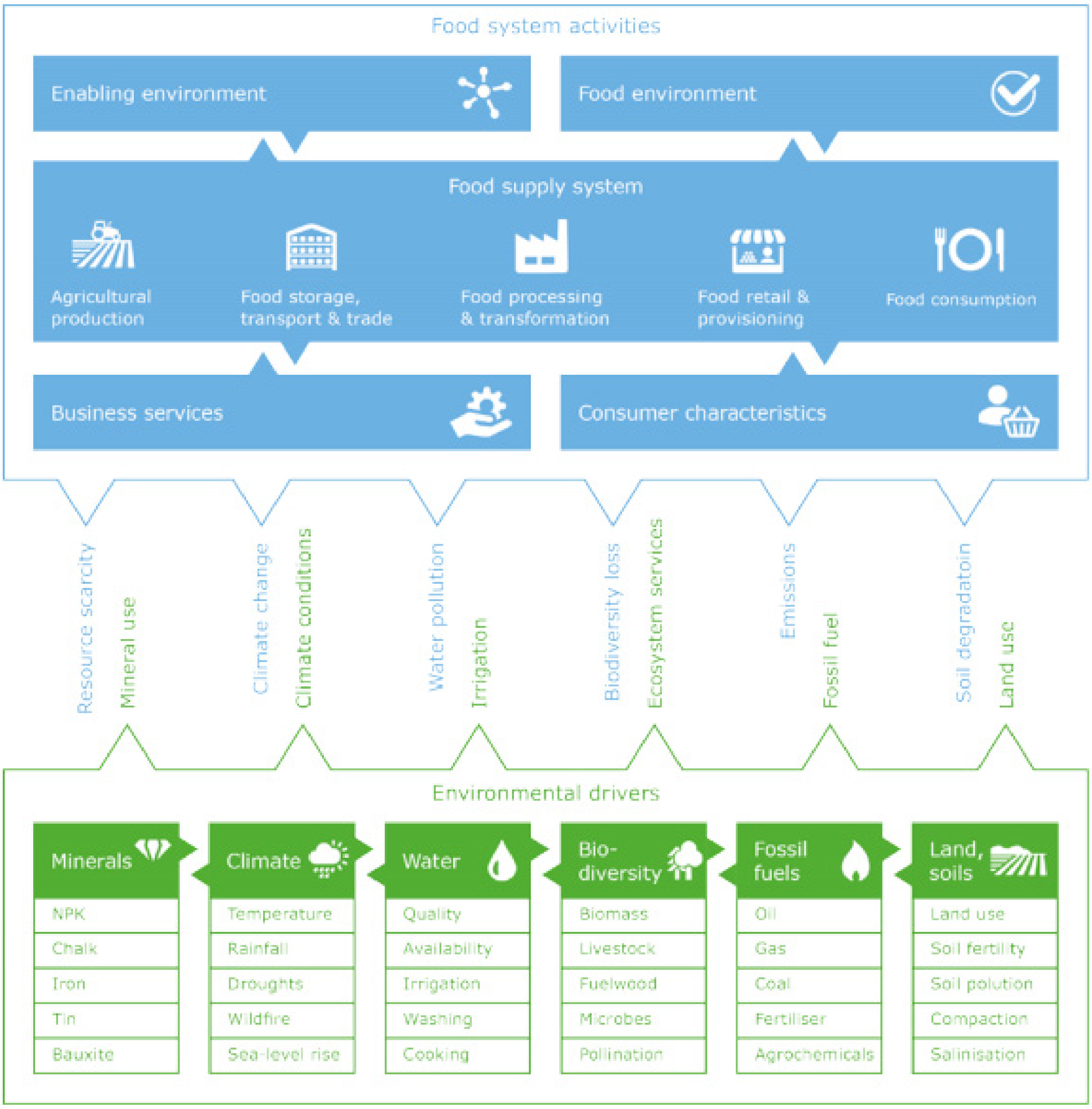

Figure 7 *Environmental drivers FSA (van Berkum et al.,2018).*

The impacts are classified in two effects:

1. Direct effect, showing a direct link from salinity to the driver (e.g., mineral salts are directly effecting the water) and thus a direct arrow is displayed (figure 4).
2. Indirect effect, salinity connects via another medium with the driver connected via 1+ arrows (figure 4).

The colors in the table 2 correspond with the food system driver (socio-economic drivers are orange and environmental drivers are green).

Table 2 *Linking salinity with the socio-economic/environmental food system drivers.*

Driver	Indirect – Direct effect	Explanation
Markets	Indirect effects of salinization.	The availability of certain crops is influence by the salinity. Some crops thrive and other experience negative yield responses. This leads to more/ less supply of certain crops, leading to a different market situation than without salinity (Munns, R & Gilliham, 2015). In this way, import could also be affected by increasing the need for certain crops
Policies	Indirect effect on salinization	One of the influenced drivers is the policy. This can be explained by an example of Egypt. In this country there is a policy to use saltwater for agriculture. More information can be found in the sub-chapter on salinization and policies (an example for Australia is McCann & Hafdahl, (2007).
Science technology	Indirect effect on salinization.	Science and technology can support identification and quantification of salinization Also it can provide solutions for salinization. For example, desalinization techniques (Younos& Tulou 2005). crops gen modifications (Mahajan& Tuteja 2005), large scale predictions for salinity (Gorji et al.,2015).
Social Organizations	Indirect effects on salinization	A socio-economic driver that is not directly researched, are the social organizations. As salinity might affect the crop-production and thus income, stakeholders might be inclined to act communally through social-organizations (Szabo et al.,2016)
Individual factors	Indirect effects on salinization	The food demand, and thus crop production depends on consumer needs. With this respect, salinity influences the taste of crops (Petersen et al., 1998).
Minerals	Direct effect on salinization	Salinity has a direct effect on type of minerals and distribution of minerals in the soil and water. This impact takes place at cellular level but has big consequences for the soil quality and water quality (FAO,1988)
Climate	Direct effect on salinization	This is a special direct effect as it influences the whole system salinity. The first effect is the sea-level rise in coastal regions this leads to intrusion of saltwater in-land, influencing the salinity levels in water and soil in-land. Also changing rainfall patterns and changing river discharge have influence on salinity levels, either intensifying the levels (by less availability of fresh water) or decreasing (by more intense rainfall in a certain period) (Durack et al., 2013). (Connor et al.,2012).

Driver	Indirect – Direct effect	Explanation
Water	Direct effect on salinization	The minerals dissolve directly into the water, influencing the water quality (FAO,1985).
Biodiversity	Indirect effect on salinization	The biodiversity driver is indirect impacted by salinity. When environments are more saline certain animals, crops and environments are shaped. By changing the delicate balance within the ecosystem with increasing salt levels, the biodiversity might also change in the ecosystem (Telesh et al., 2013)
Fossil fuels	Indirect effect on salinization	The fossil fuel driver is indirectly affected by salinity. Several effects can be considered such as pumping aquifer for oil and gas, this influences the groundwater quality. (Kamra et al.,2002). Salinity can also be used as energy source as a cleaner source for pumping oil and gas (Li, et al.,2018)
Land, soils	Direct effect on salinization	The minerals that cause salinization are naturally occurring in the earth. The texture and structure of the soil also contributes to the salinization potential (Warrence et al.,2002). Therefore, salinization has direct impact on the distribution and occurrence of these minerals in the soil.

Example socio-economic driver: Agricultural policies and relations with salinity

Agricultural policies throughout the world are particularly focused on maintaining or increasing food production and ensuring food security and safety. Such policies are required to feed populations and maintaining societal stability and prosperity. It is for this reason that multiple countries subsidize agricultural production. Depending on location, countries may focus on maximizing food self-sufficiency production to reduce dependency on other countries. This type of policies can be observed particularly in the MENA region after the recent food crisis. Food related policies are also often in the context of international trade related to cash crops production (e.g. cotton, high valuable fruits and vegetables) to gain income to the national economy. More recently, increasing attention for sustainable agricultural production arise, particularly within the scope of climate change. In the EU for instance, financial support to sustainable agriculture and green activities were included since 2013 (Jongeneel, 2020). One of the common EU agricultural goals is now to help tackle climate change and the sustainable management of natural resources (European Union, 2019). Also, in other countries such as Turkey, United States and others, objectives related to sustainable agriculture are embedded in policies (for instance: Dellan and Bolat, 2019; Rausser and Zilberman, 2014). As such increasing attention is given to include environmental outcomes in agricultural policies. However, agricultural policies that are specifically aimed on addressing or mitigating agricultural systems to (increasing) saline conditions have not been found by the authors. Moreover, the agricultural sector is facing a number of challenges related to meeting future demands for food, fuel, fibre and ecosystem services in a more sustainable manner in the context of a changing climate that still need to be addressed. In this context, policymakers need to create a better and more coherent policy environment to meet food demand sustainably (OECD, 2020). One of these challenges include the risks of increasing water and soil salinization in agricultural systems and inclusion of measures, interventions and strategies to address those.

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