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WAGENINGEN UNIVERSITY & RESEARCH

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Dit rapport onderzoekt de uitdagingen van verzilting in de landbouw en vergelijkt Argentinië met Nederland. In Argentinië wordt de verziltingsaanpak grotendeels vanuit de boeren gestuurd en benut vooral technische oplossingen voor verzilting zoals zouttolerante gewassen, bio-drainage en regenwateropvang In Nederland is de verziltingsaanpak geïnstitutionaliseerd met een leidende rol voor (nationale) overheidsinstanties en waterschappen. De studie verkent hoe verzilting adaptatiestrategieën van Argentinië de Nederlandse praktijken kunnen informeren en vice versa. Met de FAO-richtlijnen als kader identificeert het rapport schaalbare, context specifieke oplossingen voor verziltingsbeheer. De bevindingen ondersteunen beleidsmakers bij het implementeren van duurzame landbouwpraktijken die aansluiten bij internationale standaarden.

This report examines salinisation challenges in agriculture, comparing Argentina and the Netherlands. Argentina relies on grassroots, farmer-led governance and community-driven technical solutions such as salt-tolerant crops, bio-drainage, and rainwater harvesting. In contrast, the Netherlands water and salinity policy and management is highly institutionalised, with (national) government bodies and water boards taking the lead. The study explores how Argentina's adaptive strategies can inform Dutch practices and vice versa. Using FAO farmer guidelines as a framework, the report identifies scalable, context-specific solutions to improve salinity management. The findings aim to support policymakers in implementing resilient agricultural practices aligned with international standards to address salinisation challenges effectively.

Keywords: Salinisation, Argentina, FAO farmer guidelines, Food security

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Samenvatting

Verzilting vormt wereldwijd een steeds groter probleem voor voedselzekerheid en ecosystemen. Het vaker voorkomen van extreme weersomstandigheden zoals droogte en hogere temperaturen onder de invloed van klimaatverandering zullen dit probleem in de toekomst verergeren. Zowel in Argentinië als Nederland komt verzilting voor, maar de oorzaken en de strategieën om ermee om te gaan variëren aanzienlijk. Door de verschillende toegepaste verzilting strategieën kan van elkaar geleerd worden. In dit rapport worden de verziltingsstrategieën geanalyseerd en vergeleken zowel op bestuurlijk als technische gebied (bodem, water en gewasbeheer). Dit wordt gedaan aan de hand van de FAO-richtlijn "Farmers' Guidelines on Soil and Water Management in Salt-affected Areas"[1]. Hiermee is onderzocht hoe de toegepaste strategieën in Argentinië mogelijk ook gebruikt kunnen worden in Nederland. Om de mogelijke toe- en aanpasbaarheid van de Argentijnse strategieën naar de Nederlandse context te onderzoeken kijken we naar verschillende schaling mechanismen schalen (horizontaal, verticaal en functioneel).

Het onderzoeksgebied in Argentinië richt zich voornamelijk op de Pampas-regio. De belangrijk oorzaken voor verzilting zijn hier de vlakke topografie en de beperkte natuurlijke drainage. Daarnaast heeft de intensivering van de landbouw het verziltingsprobleem verergerd. In de afgelopen decennia heeft een transitie plaats gevonden van diep wortelende inheemse graslanden naar ondiep wortelende gewassen zoals sojabonen en mais. Hierdoor is de grondwaterstand gestegen, wat resulteert in een hoger risico voor verzilting. In Nederland is verzilting voornamelijk geconcentreerd in de kustgebieden. Zoute kwel en overstromingen, in combinatie met een stijgende zeespiegel, zijn hier de belangrijke oorzaken van het verziltingsproces. Ondanks de verschillende oorzaken en context hebben beide landen strategieën ontwikkeld om op een effectieve manier met verzilting om te gaan. Deze strategieën zijn opgedeeld in bestuurlijke strategieën en technische strategieën.

De manier van bestuur speelt een belangrijke rol bij het aanpakken van verzilting. In Argentinië wordt de verziltingsaanpak grotendeels vanuit de boeren gestuurd. In lokale initiatieven, zoals het CREA-netwerk, waarin boeren samenwerken en kennis delen, wordt het grootste gedeelte van het verziltingsbeheer bepaald. Deze bottom-up aanpak biedt flexibiliteit en stimuleert lokale innovatie. Echter, met meer nationale coördinatie zou het beleid effectiever geïmplementeerd kunnen worden. Er zijn al nationale instellingen zoals INTA (Instituto Nacional de Tecnología Agropecuaria) die onderzoek ondersteunen en hieraan kunnen bijdragen. Tevens helpen internationale samenwerkingsverbanden, zoals het FAO Global Soil Doctors programma, bij aan capaciteitsopbouw.

In Nederland is de verziltingsaanpak geïnstitutionaliseerd met een leidende rol voor (nationale) overheidsinstanties en waterschappen. Dit model biedt voordelen, zoals uniforme beleidsuitvoering en een consistentie van onderhoud van de infrastructuur (e.g. onderhouden van dijken en waterpeil reguleren). Echter, uniformiteit leidt ook tot minder flexibiliteit, wat innovatie kan belemmeren, vooral op lokaal niveau. Hier kunnen waardevolle lessen geleerd worden van de Argentijnse aanpak: door bottom-up elementen meer te integreren in het Nederlandse systeem kan lokaal maatwerk worden gestimuleerd, terwijl nationale coördinatie behouden blijft.

Technische strategieën vormen een ander belangrijk aspect van verziltingsbeheer in beide landen. In Argentinië zijn diverse innovatieve technieken toegepast: (gematigde) zouttolerante gewassen, zoals sojabonen, verbouwen helpt opbrengstverliezen te beperken bij verzilting. Agronomische aanpassingen, zoals het optimaliseren van zaaidata, verbeteren van het watergebruik en verhogen van de weerbaarheid van gewassen tegen droogte helpen ook bij verzilting. Om de grondwaterstanden te reguleren kan worden overwogen om gebruik te maken van diepgewortelde bomen zoals eucalyptus. Het risico bestaat wel dat er zoutophoping in de wortelzone ontstaat. Tevens worden regenwateropvangsystemen ingezet om zout uit de bodem te spoelen en daarmee aan verbetering van de bodemgezondheid bij te dragen.

[1] Geschiktheid FAO Farmers' Guidelines on Soil and Water Management in Salt-affected Areas toepassing in Nederland zijn verder onderzocht en uitgewerkt in Knol et al., 2024.

Bodemverbeteringstechnieken, zoals het gebruik van gips en organisch materiaal, dragen daarnaast ook bij aan het verbeteren van de bodemstructuur en verminderen van de sodiciteit.

Deze technische oplossingen kunnen voor de Nederlandse situatie ook relevant zijn, maar moeten eerst worden aangepast aan de lokale omstandigheden. Zouttolerante gewassen (en/of halofyten) zijn bijvoorbeeld geschikt voor kustgebieden zoals Zeeland, waar verzilting en landbouw belangrijke thema's zijn. Regenwateropvang kan worden geïntegreerd in lokale waterbeheerstrategieën om zowel zoutophoping als droogte tegen te gaan. Bio-drainage is toepasbaar in gebieden met hoge grondwaterstanden. Hierbij moet door zorgvuldig beleid worden voorkomen dat de waterbalans wordt verstoord. De analyse volgens de FAO- verzilting richtlijnen voor boeren geeft aan dat de strategieën alleen succesvol kunnen zijn als deze worden ondersteund door adequaat bestuur en adequate financiële middelen.

De toepassing van zowel de bestuurlijke als de technische Argentijnse strategieën in Nederland vereisen een systematische aanpak. Voor Nederland zijn vooral de flexibiliteit en kennisdeling van Argentijnse boerennetwerken, zoals het CREA-model, interessant. Door dergelijke netwerken verder te ontwikkelen in Nederland kan lokale innovatie worden gestimuleerd en kunnen boeren meer betrokken worden bij het verziltingsbeheer. Tegelijkertijd kan Nederland, Argentinië ondersteunen met het institutionaliseren van water- en verziltingsbeheer. Samenwerkingen tussen onderzoek en praktijk, zoals die in Argentinië worden toegepast, kunnen in beide landen worden versterkt om innovatie en adaptatie te versnellen. Daarnaast biedt de ontwikkeling van nieuwe markten voor zouttolerante gewassen, zoals halofyten, economische kansen die beide landen kunnen benutten.

De belangrijkste lessen uit deze analyse benadrukken het belang van samenwerking op dit onderwerp, aanpassingsvermogen en innovatie. Door het combineren van bottom-up benaderingen met sterke institutionele coördinatie kunnen beide landen effectievere en duurzamere oplossingen ontwikkelen voor verziltingsproblemen. Integratie van technische, beleids- en financiële strategieën is essentieel voor een toekomstbestendig en weerbaar voedselsysteem in beide landen.

Summary

Salinisation creates growing challenges for food security and ecosystems worldwide. There has been more frequent occurrence of extreme weather conditions, such as drought, and, with temperatures rising further due to climate change, the challenges are likely to intensify even more in the future. Many countries are dealing with the impacts of salinity. Argentina and the Netherlands are no exception. Both are affected by salinisation. However, differences occur in the causes of it in the two countries, and each country's strategy to manage it. Lessons can be learned through a comparison of the strategies of each of the countries. We carried out a comparison using the "FAO Farmers' Guidelines on Soil and Water Management in Salt-affected Areas[2]" as a guide. It was of particular interest in the investigation to find out how the strategies applied in Argentina could possibly also be used in the Netherlands. To research the possible applicability and adaptability of the strategies to the Dutch context, the concept of scaling (horizontal, vertical and functional) was used.

In Argentina, the focus is on the Pampas region, where the flat topography and limited natural drainage are the main causes of salinisation. Agricultural intensification has further increased the problem. Over recent decades, a transition from deep-rooted native grasslands to shallow-rooted crops, such as soybeans and maize, has caused groundwater levels to rise, enhancing the risk of salinisation. In the Netherlands, salinisation is mainly concentrated in coastal areas, where saltwater intrusion, sea-level rise, and flooding are important factors. Despite these differences, both countries have developed strategies to deal with salinisation. These strategies can be divided into management strategies and technical strategies.

Governance plays an important role in addressing salinisation. In Argentina, salinity management is largely farmer-driven. Local initiatives, such as the CREA network, in which farmers collaborate and share knowledge, are central to managing salinisation. This bottom-up approach offers flexibility and fosters local innovation. However, national coordination could make policy implementation more effective. Institutions, such as INTA (Instituto Nacional de Tecnología Agropecuaria), already support research and could strengthen these efforts further. International collaborations, such as the FAO (Food and Agriculture Organization of the United Nations) Global Soil Doctors programme, also contribute by building capacity.

In the Netherlands, water and salinity policy and management is highly institutionalised, with (national) Government bodies and water boards taking the lead. This system provides advantages, such as uniform policy implementation and consistent infrastructure maintenance, for example, through dike maintenance and water-level regulation. However, this uniformity can also hinder flexibility, which may slow down innovation, especially at the local level. The Dutch system could benefit from some integration of bottom-up elements, inspired by the Argentinian approach, that encourage local solutions while maintaining national coordination.

Technical strategies form another important aspect of salinity management. In Argentina, a range of techniques have been applied. Growing (moderately) salt-tolerant crops, such as soybeans, helps mitigate yield losses caused by salinity. Agronomic adjustments, such as optimising planting dates, improving water use efficiency, and increasing crop resilience to drought, also play an important role. Planting deep-rooted trees, such as eucalyptus, could help manage groundwater levels, although this could increase the risk of salt accumulation in the root zone. Additionally, rainwater harvesting systems are used to flush salt from the soil, to improve soil health. Soil amendments, such as adding gypsum and organic material, further enhance soil structure and reduce sodicity.

These technical strategies could also be relevant for the Netherlands but need to be adapted to local conditions. For instance, salt-tolerant crops and halophytes, are particularly suited for growth in coastal areas, such as the Dutch Province of Zeeland, where salinisation is a pressing issue. Rainwater harvesting

[2] The suitability of FAO farmers guidelines for application in the Netherlands has been further researched and elaborated in Knol et al., 2024.

could be integrated into water management strategies to address both salinity and drought. Bio-drainage could also be effective in regions with high groundwater levels, provided that the policies implemented ensure that the water balance is not disrupted. According to the FAO Farmers' Guidelines on Soil and Water Management in Salt-Affected Areas, these strategies are most successful if supported by governance and adequate financial resources.

The potential for adapting these strategies to the Dutch context was analysed through the concept of scaling. Horizontal scaling refers to the replication of solutions across regions with similar conditions. Vertical scaling involves the embedment of them into governance frameworks. While functional scaling integrates salinity management with other sustainable agricultural practices.

The findings underscore the potential for mutual learning. The Netherlands can further learn from Argentina's grassroots, farmer-led governance, which stimulates local innovation and knowledge sharing. Argentina could benefit from the Netherlands' experience in institutionalising water management and advanced technologies. Strengthening collaboration between research and practice, which is already occurring in Argentina, could accelerate innovation and adaptation in both countries. Additionally, the development of new markets for salt-tolerant crops, such as halophytes, provides economic opportunities for both countries.

The key lessons derived from this analysis highlight the importance of cooperation, adaptability, and innovation. By combining bottom-up approaches with strong national coordination, both countries can develop more effective and sustainable solutions for salinisation. Integrating technical, governance, and financial strategies is essential for building a future-proof and resilient food system.

1 Introduction

Salinity[3] challenges are increasing worldwide due to the effects of climate change. Climate change events, such as (coastal) flooding and droughts are linked to increased salinisation (Majeed and Muhammad, 2019;Hassani et al.,2021). This has implications for food security and ecosystem health. Given these impacts, the need to develop effective salinity management strategies is urgent. While many countries face salinity issues in their own contexts, there is added value in learning from each other's experiences and approaches.

Both Argentina and the Netherlands currently have issues around salinisation to deal with, however, the environmental and socio-economic conditions of each differ. In Argentina, salinisation predominantly affects the semi-arid Pampas region. Farmers there, often supported by the private sector, have formed cooperative networks to exchange knowledge and develop adaptive strategies.

In contrast, salinisation in the Netherlands is primarily driven by coastal influences, including saline seepage (upward movement of saline groundwater to the surface) and periodic flooding, increased by rising sea levels. The Netherlands benefit from a strong institutional governance structure, within which Government agencies and water boards play a pivotal role.

Despite these contextual differences, both countries have developed governance and technical solutions specific to their challenges. These different approaches provide opportunities for mutual learning, particularly in integrating technical innovations with governance frameworks that are suited to local needs.

This report starts by briefly introducing the context, the research questions and objectives. Chapter 2 describes the methodology, including field observations, stakeholder interviews, and content analysis, which together form the foundation of this research. Chapters 3 provides context and an in-depth examination of governance landscapes in salinity management. Chapter 5 explores the technical solutions implemented in Argentina, focusing on soil, water, and crop management practices. Building upon this, Chapter 6 discusses the potential for scaling and adapting these solutions to different contexts, such as in the Netherlands. The report concludes in Chapter 7 with findings and recommendations.

1.1 Research questions and goals

The following overarching question was used to address the previously formulated need and guide research:

Drawing on the FAO farmer guidelines and Argentinian experience, how can the identified solutions in governance and technical salinity management practices be adapted and scaled for application in other contexts, such as the Netherlands?

This question can be approached via three research-questions:
1. What is the **governance landscape in Argentina,** including state, sub and non-state actors for salinity management in the country?
2. What are the short- to long-term **technical solutions** in Argentina, including management of soil, water and crops for salinity management in the country?
3. How can the identified solutions from Argentina be **adapted and scaled** to align with the Dutch environment?

[3] Salinity refers to the concentration of dissolved salts in water or soil. In soil, it is commonly quantified by measuring the electrical conductivity (EC) of a saturated soil extract, expressed in deciSiemens per meter (dS/m) (Rengasamy,2010)

To answer the questions, a main goal and sub-goals were formulated.

Main goal:
To analyse and address the research questions and recommendations in governance and technical salinity management practices in the Netherlands based on the FAO farmer guidelines.

Specific goals are to:
- Map the governance landscape for salinity management in Argentina.
- Identify the soil, water and crop management practices in Argentina.
- Compare the Argentinian governance and technical solutions to FAO farmer guidelines.
- Formulate practical recommendations in governance and technical salinity management practices in the Netherlands at various spatial, temporal and institutional scales.

2 Approach

To address the research questions formulated in Chapter 1, a series of activities were undertaken. Central to this research was a field mission in Argentina. The activities provided a foundation for analysis of Argentina's salinity management practices, with guidance from *"Farmers' Guidelines on Soil and Water Management in Salt-Affected Areas"* (FAO and ICBA, 2023). From here on, referred to as 'the FAO farmer guidelines' in this report. These guidelines provide practical advice for farmers in dealing with soil salinity and sodicity. The guidelines cover the causes and effects of salinity and sodicity on crops, methods for assessing soil and water salinity, and strategies for effective management. Key recommendations include irrigation techniques, soil amendments, land levelling, and crop selection to mitigate the negative impacts of salinity and sodicity on agricultural productivity. These guidelines served as a basis for understanding and reflecting on local practices and exploring potential scaling and adaptions to other contexts, such as the Netherlands.

The approach includes a combination of content analysis, field research, stakeholder engagement, and systematic evaluations. The rest of this Chapter describes each activity in detail and outlines its contribution towards answering the research questions and laying a contextual foundation for adapting these solutions.

2.1 Content analysis

A content analysis focused on Argentina's environmental conditions and salinity management practices was conducted. This phase served as basis for answering Research Questions 1 and 2, as it provided explanation and clarity on the governance and technical solutions currently in place. This analysis informed subsequent activities by providing an outline of the existing technical and governance landscape of salinity challenges in Argentina.

2.2 Mission Argentina

Observations were made and interactions with stakeholders were held during a one-week mission to Argentina that took place in August 2024. The main goal of the mission was to observe, identify, and describe the current solutions applied to manage salinity. The location selected was América, situated close to the Pampas region (Figure 1).

In addition to observations, conversations were held with a variety of stakeholders to deepen the understanding of both governance and technical solutions for salinity management. The conversations allowed for further exploration of the challenges and opportunities faced by these stakeholders. The conversations were structured according translation of the FAO farmer guidelines. The guidelines for these conversations can be found in Annex 1. An important source of information in the field was also the observations of The Salt Doctors (Salt Doctors, 2024). These observations have been incorporated in Chapter 6 on technical solutions.

The Agroinnova site was selected as an observation and meeting site due to its proximity to several on-going experiments related to agriculture and salinity in the area, and as a practical side for connecting with different stakeholders in the region. The site is located in the Buenos Aires province of Argentina and is very close to the Pampas region. It falls within the temperate climate zone of the Pampas region. The area normally experiences a mild climate with significant seasonal variations. Summers (December to February) are typically warm, with average high temperatures around 30°C and low temperatures of around 17°C. Precipitation is moderate during this period, averaging approximately 85-105 mm per month. Winters (June to August) are normally mild to cool, with average highs of around 15°C and lows of around 7°C. Rainfall during winter is less frequent, averaging about 60-70 mm per month (Blue Planet Biomes, 2020; World Bank Group, n.d.).

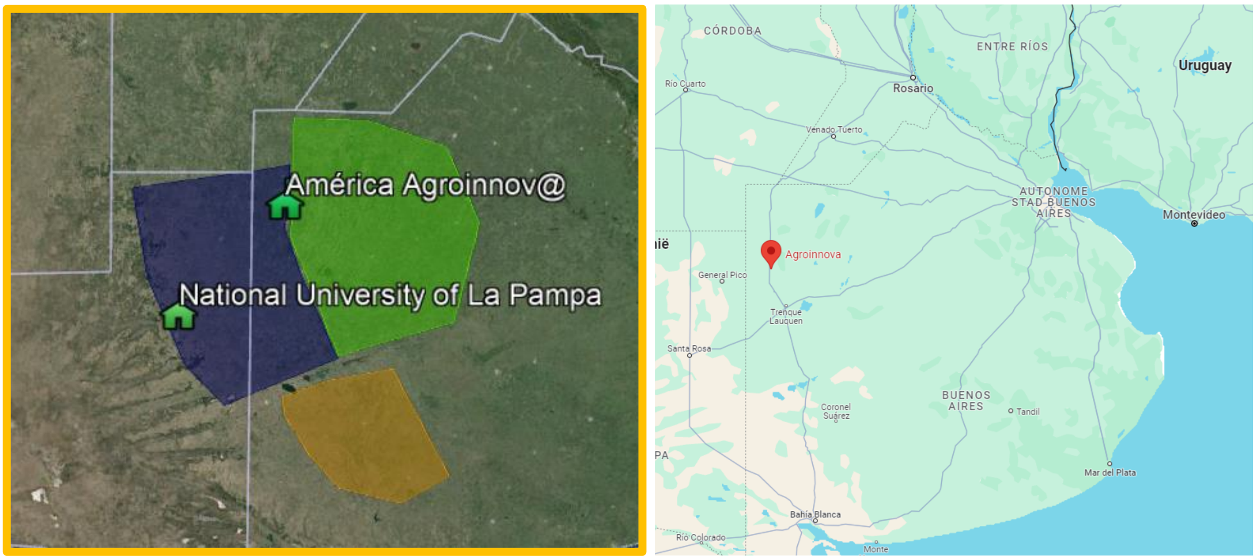

Figure 1 *Case study area location (Google maps, 2024).*

2.3 Governance landscape analysis

To answer Research Question 1 regarding the governance landscape, we followed the methodology of Negacz et al. (2022), to map international cooperative initiatives. In this report, the focus was on both international cooperative initiatives (ICIs) and national (Argentinian) cooperative initiatives. International initiatives can be defined as collaborations from multiple national, international, or transnational institutions that can either be from the public sector, civil society organisations, or government bodies from different levels (supranational, national, regional, or local). These initiatives share a common governance objective to influence salinity policies and practices within their member organisations or a wider community. They perform key governance functions to achieve their objectives effectively (Widerberg et al., 2016).

The data collection included the following three steps:
1. Salinity-related initiatives were collected through an examination of existing databases, including the SALAD project database and Saline Agri Map (Negacz et al.,2022).
2. A systematic internet search using a predefined set of keywords (Annex 2) was conducted, applying a snowballing approach. The collected initiatives were then catalogued in a database.
3. Expert interviews were conducted in Argentina to identify more national- and international initiatives.

Next, selected variables, including types of actors, governance functions, thematic foci, and Sustainable Development Goals, were collected. The database was validated through both an automated keyword analysis and an expert review to ensure data relevance (Annex 3). The variables were subsequently analysed using descriptive statistics and a governance triangle to identify government, corporate or civil society actors, developed by Abbott and Snidal (2009a; 2009b). In addition, there were open interviews conducted with a wide range of experts that work in the sectors related to salinity including representatives of financial institutions (3), international organisations (3), education (4), government (2), farmers and entrepreneurs (with six interviewees). The interviews were pre-arranged and conducted in person. The interviews were summarised, and the main findings are presented in this report.

2.4 FAO farmer guidelines matrix

To reflect on the local governance and technical solutions implemented, the FAO farmer guidelines were organised into a structured, colour-coded matrix. This matrix provided a systematic way to categorise and analyse the governance and technical solutions observed based on their current implementation status. Additionally, it served as a tool for assessing the potential for these solutions to be adapted and scaled to other contexts, such as the Netherlands (Chapter 7). In this report, as already mentioned in the summary, the in-depth exploration of the application of the FAO farmer guidelines in the Netherlands were published by Knol et al., 2024.

The following colour-coding was used:

- **Green**: Fully implemented solutions, showing complete adherence to FAO farmer guidelines and effective application in the field.
- **Yellow**: Partially implemented solutions, reflecting partial alignment with the guidelines or limited application.
- **Orange**: Not fully implemented, more not implemented than implemented.
- **Red**: Unimplemented solutions, indicating areas where FAO recommendations have not yet been adopted or where significant barriers remain.

2.5 Upscaling and adapting

The concept of scaling was explored to answer Research Question 3. In the context of salinisation and agriculture, upscaling adaptation strategies means implementing solutions on a larger scale to address widespread salinity challenges (Deolu-Ajayi et al., forthcoming). There are different forms of scaling. In their review of upscaling, Guentchev et al. (2023) identify three main forms of scaling:

- **Horizontal Scaling**: This approach involves replicating a solution to reach a broader audience with minimal modification, such as transferring technology from controlled environments (e.g. greenhouses to open fields), or from one farmer to another. For saline agriculture, horizontal scaling allows innovations to move from experimental phases to practical applications on a wider scale.
- **Vertical Scaling:** When adaptation strategies are integrated into policy and institutional frameworks, creating a supportive environment, this is known as vertical scaling. In the Dutch context, this could involve government policies that allocate funding to support saline agriculture initiatives, effectively embedding these practices within national agricultural policy.
- **Functional Scaling:** This type involves broadening the adaptation initiative’s scope, often by combining it with other activities. For example, coupling saline agriculture with agritourism could both diversify income sources and raise public awareness about saline agriculture’s potential benefits.

These scaling approaches were applied to evaluate the potential for adapting and implementing the identified governance and technical solutions (Research Questions 2 and 3) to other contexts, such as the Netherlands. Some of the solutions identified are not (fully) implemented in Argentina according to the FAO farmer guidelines but are interesting for both countries to further investigate for possible scaling and adaptation. These boxes have been designated the colour blue with dark blue being most suitable and light blue being less suitable for adaptation and scaling. The findings are presented in Table 3.

3 Context and background

This Chapter provides an overview of the context and background to better understand the local conditions in Argentina. It begins with a brief overview of the climate in Argentina, followed by an overview of agricultural developments in the region. Next, the impacts of climate change on the agricultural sector are examined, continuing with salinity issues in Argentina. Finally, the case study site is introduced.

3.1 Climate in Argentina

Argentina has experienced significant climate changes in recent decades. Between 1960 and 2010, temperatures in most regions outside of Patagonia increased by an average of 0.5°C. Precipitation patterns also shifted, with significant changes, and more than 200 mm of rainfall, in the eastern and southern semi-arid areas (Figures 2 and 3). Subtropical regions have seen increased rainfall since 1960. This has benefitted agricultural yields and expanded cropland into semi-arid regions. However, the increase is often associated with more frequent heavy rainfalls, which can lead to flooding in both rural and urban areas (Dove et al., 2021). The lack of natural drainage in the area with high groundwater-tables, means that water is only lost via evapotranspiration, which accumulates salts in the soil over time (Nosetto et al., 2013).

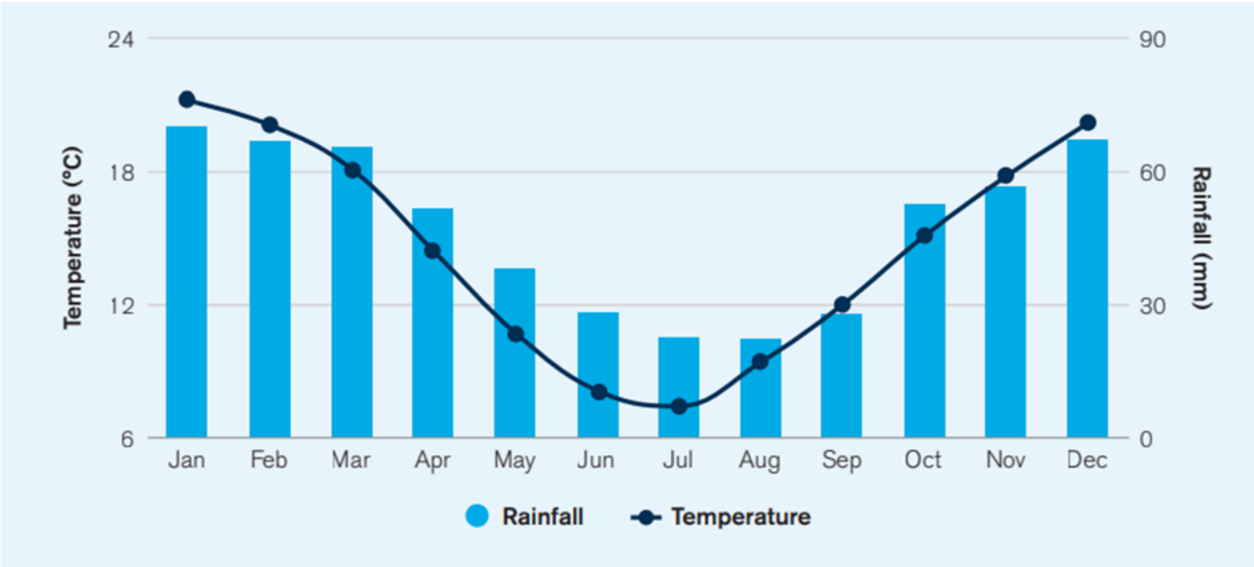

Figure 2 *Average monthly temperature and rainfall of Argentina for 1991-2020 (Dove et al., 2021).*

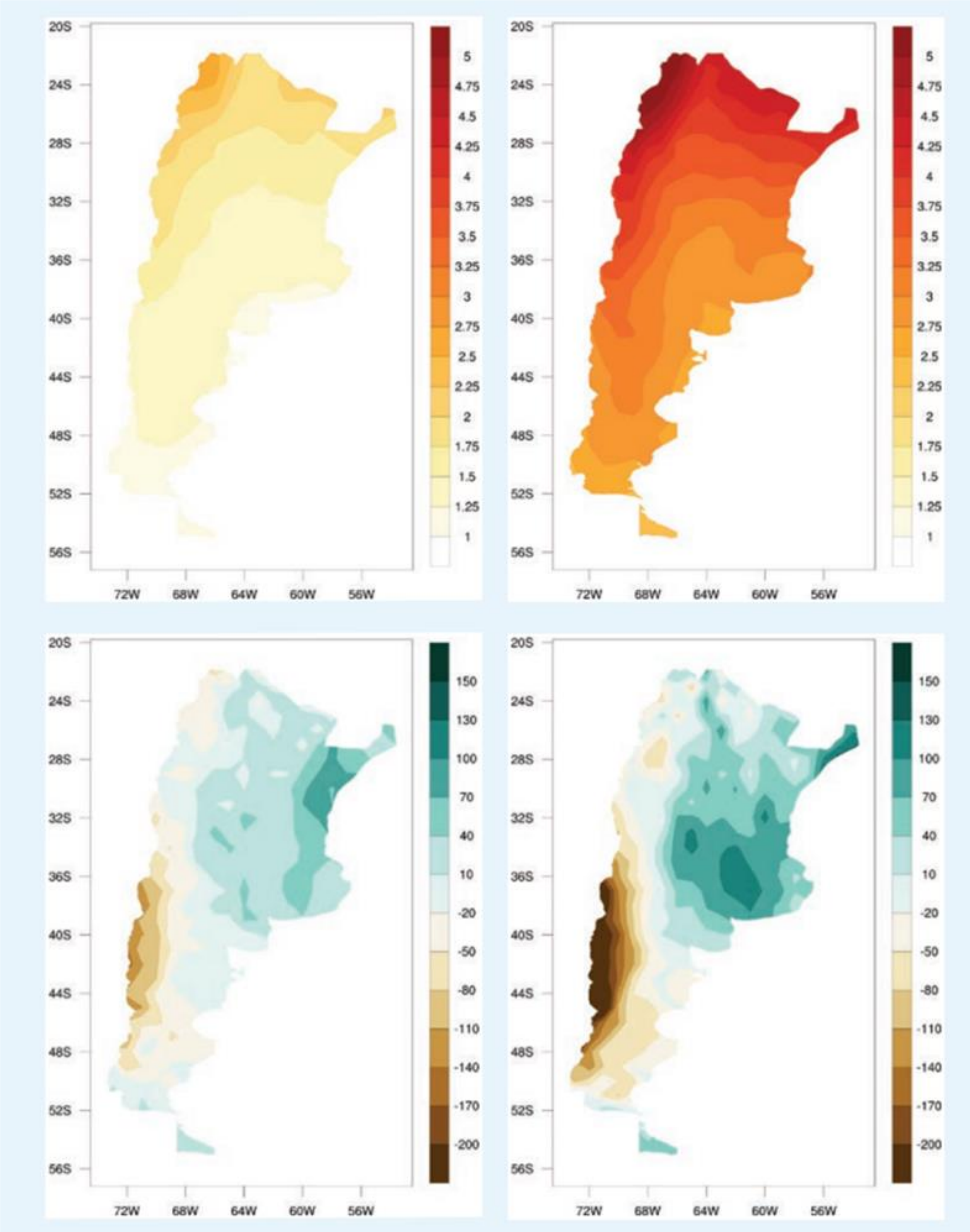

Figure 3 *CMIP5 multi-model ensemble projected change in annual temperature (top) and precipitation (bottom) by 2040-2059 and 2080-2099 (right), relative to 1986-2005 RCP 8.5 (Dove et al., 2021).*

3.2 Agriculture in Argentina

Agriculture is important to Argentina’s economy and plays a significant role in employment and export revenues. Although the contribution to GDP has declined from nearly 20% in 1959 to less than 10% in recent years, the sector remains important. From 2013 onwards, agriculture provided approximately 7% of total employment. Moreover, more than half of Argentina’s export income is earned with agricultural products. Total exports reached $86 billion in 2011 (The World Bank,2024; Food and Agriculture Organization, 2024).

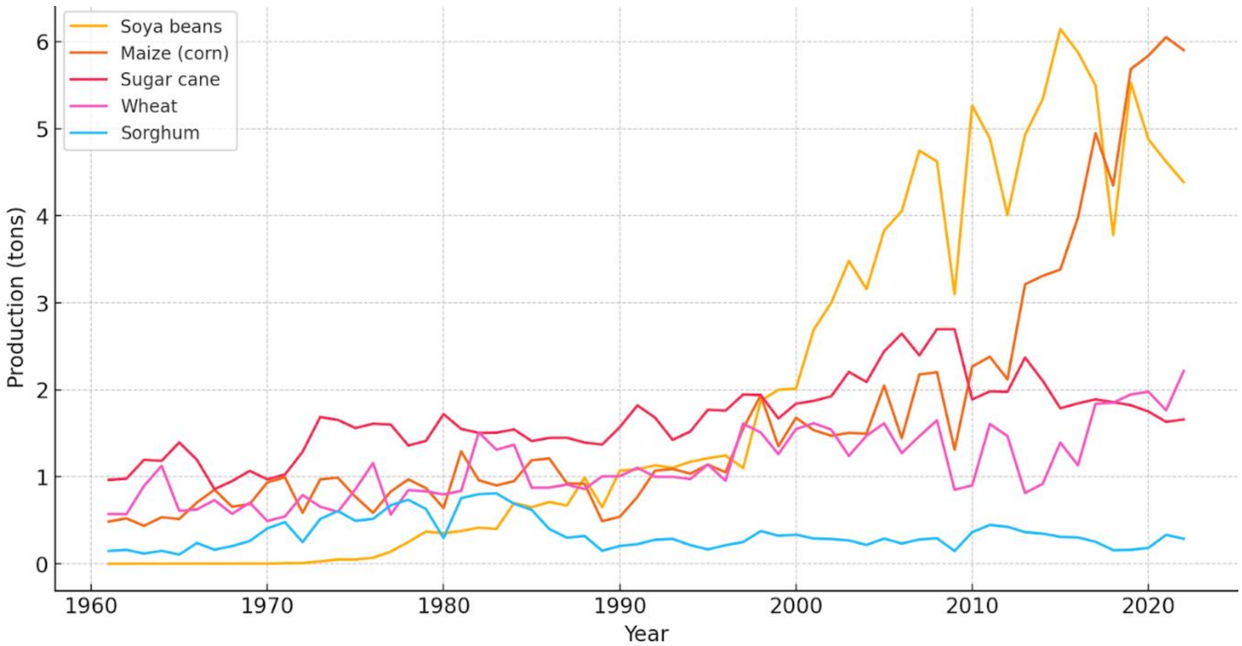

Figure 4 *Trends in production of the top five crops Argentina 1960-2020 (adjusted after FAOSTAT, n.d.).*

These crops include cereals, corn, wheat, and sorghum. The annual output of approximately 100 million tons is cultivated over 220,000 km². Oilseeds, particularly soybeans and sunflower seeds, make up the largest share in the sector, contributing 52 million tons annually. In 2018, Argentina ranked among the world’s top five producers of several commodities: soybeans (37.7 million tons), maize (43.5 million tons)(Food and Agriculture Organization, n.d.)

Over the past two decades, crop production and land use have shown significant growth, particularly for soybeans and maize. Between the late 1990s and 2020, the harvested area for soybeans increased to nearly two million hectares (from around one million ha) with productivity rising to around three tons per hectare (from approximately 1.5 tons per ha). Maize also experienced increased gains, with harvested area reaching one million hectares and yields improving to five tons per hectare. In contrast, wheat and sorghum have seen more modest productivity increases, with wheat averaging 2.5 tons per hectare and sorghum averaging three tons per hectare by 2020 (FAOSTAT, n.d.).

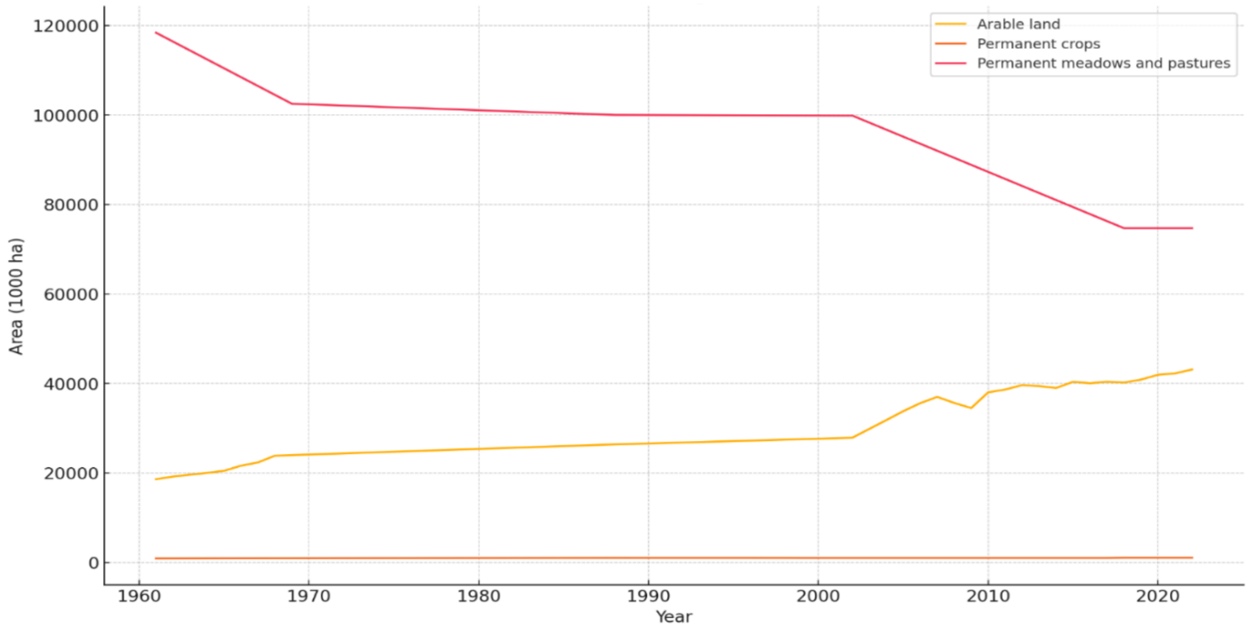

Figure 5 *Trends in Land Use in Argentina (1961-2021) (adjusted after FAOSTAT, n.d.).*

Due to the land use changes, the Argentinian landscape has shifted from a landscape that mostly consisted of native grasslands, annual crops, and pastures to one that is predominantly occupied by croplands. Soybean has emerged as the most profitable and dominant crop and most of this production is used as feed for livestock (Ritchie, 2021). The significant land use change, which has been particularly since the 1980s and has intensified further in the last decade, has resulted in the near-complete conversion of the remaining grasslands and pastures into croplands. The replacement of pastures with annual crops, known for their lower evapotranspiration rates and shallower rooting systems compared to pastures (e.g. Nosetto et al., 2012), has led to various environmental consequences (Nosetto et al., 2013). Historical water-table records, observed land use patterns, and hydrological modeling studies suggest a correlation between this widespread land use change and increased water-table levels, more frequent flooding events, and salinisation issues.

The intensification of agriculture has changed land use. As illustrated in Figure 5, permanent meadows and pastures have steadily declined since the late 1960s, replaced by arable crops. Historically, the late 19th-century demand for meat exports to Europe shaped Argentina's agricultural landscape. However, by the end of the 1960s, as international markets shifted toward grain production, wheat became a priority (Solbrig and Vigilizzo, 2000). This shift not only altered land use but also affected the hydrological cycle. Permanent grasslands, which evaporate up to twice as much water as annual crops, were replaced by less water-intensive crops (Nosetto et al., 2012).

Processed agricultural goods, including animal feed, flour, and vegetable oils, account for one-third of Argentina's export value. Livestock production, particularly beef, remains an important agricultural sector, with nearly five million tons of meat produced in 2018. Beef continues to be Argentina's primary livestock product. Notably, Argentina is also a global leader in organic agriculture, ranking as the world's second-largest producer of organic products, with three million hectares certified as organic (Bisang, 2021).

3.3 Climate change impacts on agriculture

Argentina’s agricultural sector already faces significant challenges due to climate variability. The country experiences a wide range of extreme weather events, including floods, droughts, rising temperatures, and desertification. These risks are increased in some areas by human-driven changes, such as deforestation and inefficient land use practices (Dove et al., 2021).

Focusing on extreme weather events, droughts pose a severe threat to agriculture. Particularly in key agricultural provinces such as Buenos Aires, Córdoba, La Pampa, Santa Fe, and Entre Ríos. Significant drought events in 2006–2007, 2008–2009, and 2011–2012 reduced both agricultural and livestock productivity. As climate change advances, these risks are expected to intensify. Rising temperatures and increasing desertification, especially in the north and northwest of the country (Dove et al., 2021).

Combined with climate variability, the changes are magnified, as experienced by severe droughts in 2017/2018, which impacted crop yields. Alongside this, extreme droughts are anticipated to become more frequent throughout the 21st Century (Maenza et al., 2017).

In addition, rising water demand, driven by population growth and reduced river flows, poses additional challenges. Changes in glacial melt and increased reliance on primary water sources may increase the need for groundwater use, potentially raising irrigation costs (Gomez et al., 2022).

Dove et al., 2021 also highlight that future projections with a higher maximum daily temperatures across Argentina are projected throughout the year (Figure 3). This poses a risk to both crop and livestock productivity. Livestock could be impacted by the reduced forage availability due to increased aridity. Livestock displacement is considered a high-risk scenario, as rising temperatures and evapotranspiration rates intensify heat stress on animals. This could lead to reduced milk production, lower reproductive rates, and increased vulnerability during specific periods of the year. The central Andes and humid Pampas regions are especially susceptible, with significant temperature increases expected to disrupt traditional farming practices.

Despite these increased challenges, climate change could also present opportunities for agricultural production in specific regions. In the humid Pampas, increased rainfall and extreme weather events might improve crop yields, provided that effective water management practices are in place. The Government projects stable water availability for major crops such as soybeans, maize, wheat, sunflower, and cotton until the 2040s (Dove et al., 2021). Also the projections suggest that soybean and maize yields could increase significantly due to higher summer rainfall (December to February), favoring crop production in this region. However, wheat yields may decline slightly, particularly in the central zones, where reduced spring rainfall and prolonged dry winters are expected.

3.4 Salinity in Argentina

Argentina is one of the countries with the largest saline areas globally, along with Russia, China, the United States, and Kazakhstan (Negacz et al., 2022). In regions with sub-humid climates, such as the Pampas in central Argentina, salinisation is a significant issue that affects the productivity and availability of agricultural lands (Nosetto et al., 2013). Argentina has salt marshes that occur naturally in the country. These salt marshes are found in coastal areas worldwide (Adam, 1990). Salt marshes typically are located in estuaries, deltas, lagoons, and along intertidal zones, where the limited water circulation facilitates the accumulation of fine sediments. These marshes behave like coastal wetlands and are of significant ecological importance due to the valuable ecosystem services they offer. Moreover, the salinisation of soil and groundwater can occur when afforestation is carried out within agricultural landscapes, such as the Inland Pampas of Argentina (Carol et al., 2019). The Pampas is a region filled with sediment from the Andes through wind and water. This combination created loess soils. The different sizes of sediment make the region prone to wind and water erosion.

The Pampas are known for their highly fertile and productive agricultural landscapes. However, due to the region's flat terrain, minimal natural drainage, and sub-humid climate, the groundwater-table is shallow. These conditions pose risks to local rural economies through periodic flooding and salinisation, which negatively impacts agricultural production (Nosetto et al., 2013). Salinity in the Pampas region of Argentina origins from natural sources and also human sources. The natural weathering of rocks and minerals, as well as ancient marine sediments lead to salinity. Over time, these salts accumulate through geological processes and continuous weathering. Water movements further intensify the issue through the transportation of salts to other areas.

Alongside the natural occurrence of salinity, human-induced salinity can be attributed to land use changes. Human activities, such as the use of chemical fertilisers (which contain salts) and irrigation with saline water, intensify the problem, leading to salt accumulation at or near the soil surface, particularly in low-lying areas (Nosetto et al., 2013). A consequence of this is increased salt mobilisation and migration, which can lead to decrease of the water quality through salt leaching to surface and groundwater (Jayawickreme, 2011). Another example is a decrease in water-table levels because of water infrastructure improvements. The study of Tozzi et al. (2017) found significant temporal variations showing a decrease in salinity over time. These changes in salinity also impact agricultural production. When reviewing the major crops, such as soybean, they can have a big impact on crop production. Soybean is viewed as a salt sensitive crop and yields suffer from salinisation (Chen et al.,2018). According to Maenza et al. (2017), the main drivers for salinity in the Pampas are:

1. **Topography and Shallow Groundwater**: The low-lying areas of Las Pampas have minimal natural drainage, with evapotranspiration being the primary method to drain excess water. Due to the high water-table, capillary rises bring groundwater near the surface, where evaporation leaves salts behind, contributing to surface salinity. This process is increased during dry periods, when more water evaporates, leaving even higher salt concentrations in the soil.
2. **Land Use Change**: Over the past 30 years, Las Pampas has undergone significant land use transformation from extensive grasslands, historically used for grazing livestock, to arable land for annual crops. This shift has replaced perennial native grasses, which contributed to stable evapotranspiration rates, with seasonal crops that require different water usage patterns. This change in vegetation has disrupted local hydrology and increased the risk of salinisation.
3. **Climate Factors**: Climate change has further intensified salinisation challenges. Droughts, like those in 2017/2018, have affected crop yields, while increased rainfall has led to higher groundwater levels, further raising the salinity risk in susceptible areas. Climate projections suggest a trend towards more extreme weather patterns, with an increase in drought occurrences and an overall wetter climate by the 21st Century.

4 Governance landscapes salinity

Salinisation is a multifaceted problem with impacts at individual, national and regional levels, affecting agricultural production and thus limiting economic development and prosperity. Therefore, it is necessary to find solutions that take this multifaceted nature into account. As a result, myriads of actors are required to take action to mitigate or adapt to this challenge. These actors often work together creating so-called cooperative initiatives in projects, programmes, and partnerships that bring together various actors around the common goal of managing salinity (Widerberg et al. 2016, Negacz et al., 2022). These initiatives involve non-state and sub-national actors (such as regions, companies, NGOs, communities, indigenous peoples, research institutions), often in cooperation with national governments and intergovernmental organisations.

Over the past 50 years, a large number of international cooperative initiatives have emerged around the issue of salinisation and saline agriculture worldwide. International initiatives operate across national boundaries and perform governance functions related to the implementation of salinity-related projects, as well as the provision of information and funding to achieve common goals (Widerberg et al., 2016). As such, they provide an opportunity to address the global challenge of soil and water salinisation. While governance landscape for such initiatives has been mapped for other regions (Negacz et al., 2022, Smaoui et al., forthcoming, Smaoui et al., 2024), no such analysis has yet been completed for South America.

This Chapter describes the governance landscape including state, sub and non-state actors for salinity management in Argentina based on content analysis of literature and publicly available information, participatory observation during a field mission and semi-structured interviews with stakeholders in Argentina, with the aim of stimulating a discussion on salinity governance in South America and Argentina in particular.

4.1 Cooperative initiatives in Argentina and beyond

Based on our analysis, we present the governance landscape in Argentina and neighboring countries, including 12 initiatives. We examined the actor composition, functions of the initiatives, the salinity-related issues they address, and the SDGs they aim to achieve. To provide a perspective from another global region that puts these findings in a broader context, we then compared the governance landscape with an analysis of ICIs in the Netherlands, where we explored 29 initiatives with Dutch partners or activities in the Netherlands.

The governance landscape in Argentina is dominated by initiatives led by the public sector that constitute nearly 60% of the sample. Cooperations between public and civil society represent 17% of the analysed initiatives. Public private partnerships, as well as civil society and private partnerships, each represent 8% of the total. Hybrid initiatives, including public, private and civil society actors, constitute 8% of the total, as well (Figure 6). This actor constellation indicates the governance landscape led by the public sector supported by NGOs with a notable lack of solely the private or social sector. It may be explained by regional socio-economic conditions but also by the cooperative nature of Argentinian initiatives.

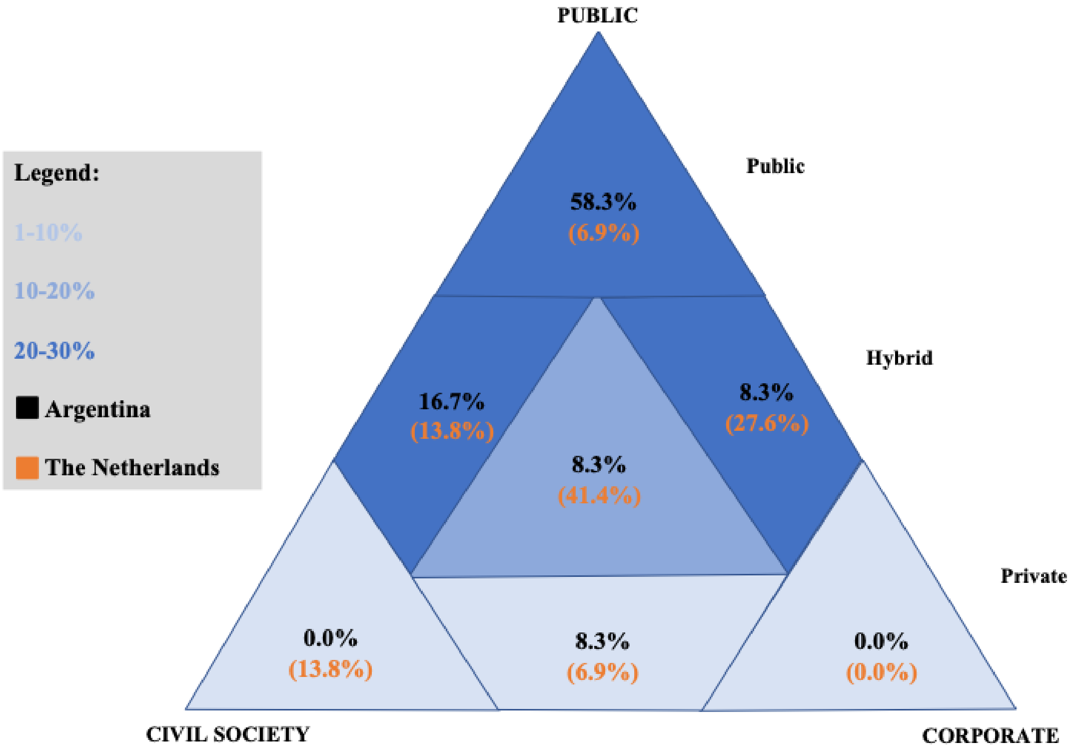

Figure 6 *The governance triangle featuring the actors composition of international cooperative initiatives for salinity in Argentina and neighbouring countries, and in brackets for The Netherlands and surrounding region. The seven zones indicate the composition of actors: (1) public, (2) corporate, (3) civil society, (4) public-private, (5) civil society-public, (6) private-civil society, (7) public-corporate-civil society (drawing from Abbott and Snidal, 2009a; 2009b).*

Looking at the Dutch governance landscape, the picture is different. Here, around 40% of initiatives are hybrid, while initiatives consisting of solely public actors account for only about 7% of the sample. Public-private partnerships are the second most common actor constellation (28%), while civil society cooperation with public actors (14%) and private actors (7%) is rather underrepresented.

In addition, we have categorised governance functions into four distinct types: standards and commitments, information and networking, financing, and operational. The standards and commitment's function includes tasks related to mandatory compliance, standards for measuring and disclosing activities, and voluntary commitments. Information and networking functions include networking, lobbying, technical advice, training, and information services. Financial functions include activities, such as the provision of financial support, grants, and funds. Finally, operational functions include technology research and development, pilot projects and dissemination of best practice (Widerberg et al., 2016).

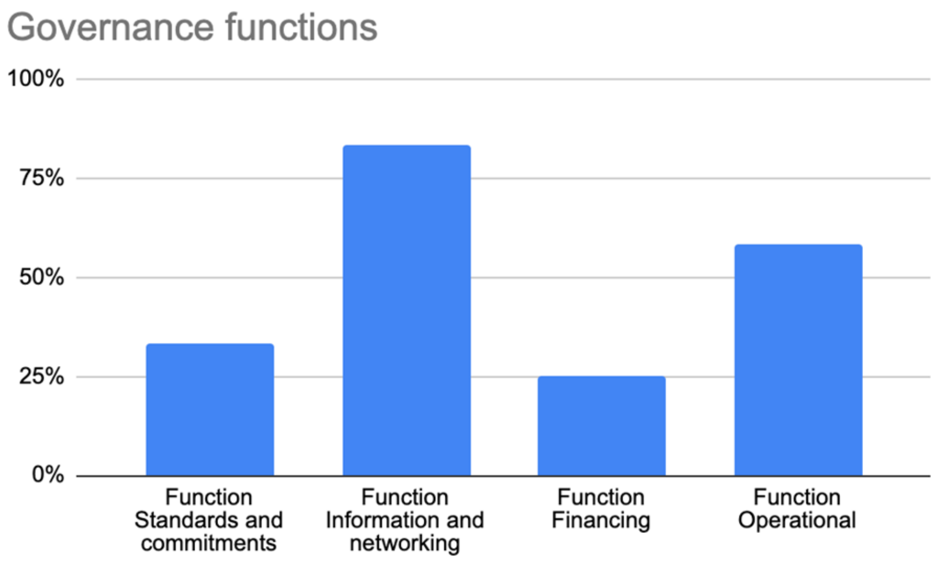

Figure 7 *South American initiatives according to governance function.*

Most of the cooperative initiatives focus on information sharing and networking (83%) (e.g. FAO Global Soil Doctors Programme in Latin America and the Caribbean), followed by operational activities (58%) (e.g. Inter-American Institute for Global Change Research (IAI)). It is noteworthy that all initiatives with operational functions also prioritise the sharing of information and networking. The least common functions are standards and commitments, as well as providing financing, with 33% and 25% respectively.

A comparison of these results with Dutch-international initiatives reveals a similar picture. Again, most initiatives (66%) are focused on information and networking functions, with operational activities accounting for 62% of the total. Standard-setting and financial support each account for another 10% of initiatives.

Looking at the regional focus, the majority of the Argentinian initiatives have international focus meaning that they involve Argentina but also other countries (50%) (Figure 8). Further, 42% initiatives focus their activities on Latin America and Caribbean countries. Additionally, one initiative (Inter-American Institute for Global Change Research (IAI)) conducts their operations broadly in all of the Americas (North, Central and South). 25% of the initiatives' headquarters are situated in South America, specifically in countries, such as Argentina and Uruguay. Conversely, 33% of the initiatives' headquarters are located in Europe, with examples including Italy (Rome) and Belgium (Brussels). It is notable that for 42% of the initiatives, the location of the headquarters is unknown.

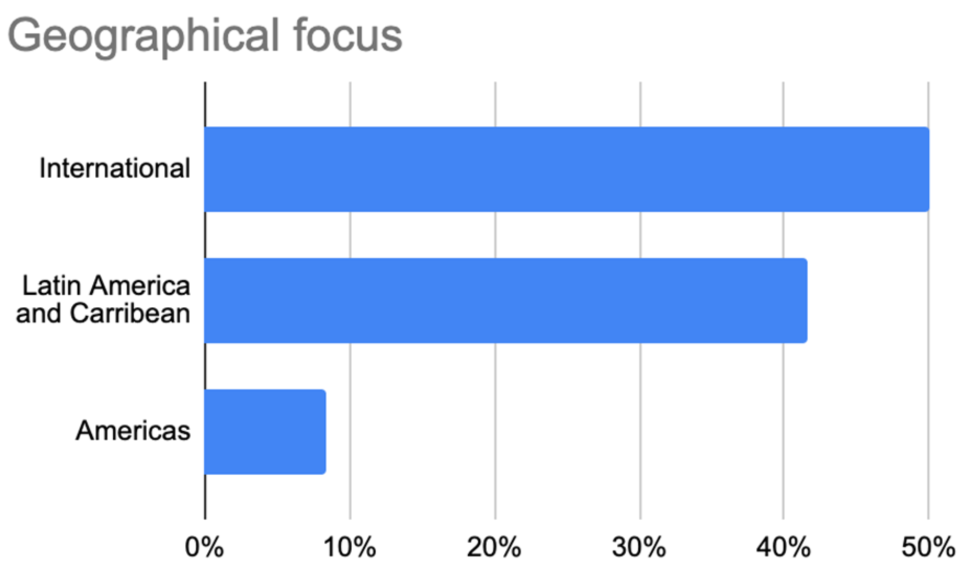

Figure 8 *Geographical distribution of South American ICIs across the focus countries.*

In contrast, 52% of the initiatives from the Dutch governance landscape are international in scope, while 48% are European only. It is interesting to note that 62% of the sample not only focus with their activities on the Netherlands, but also have their headquarters there, which demonstrates the high level of expertise in water management, as well as a willingness to develop innovative solutions to climate change impacts (Negacz et al., 2022b).

Looking at the thematic focus from the Argentinian governance landscape, the analysed initiatives focus most on soil management (75%). Salinity mitigation and adaptation raise similar interest among the initiatives (50%) followed by water management (42%). Crop management (17%), as well as halophytes (8%), seem to be less popular themes (see Figure 9).

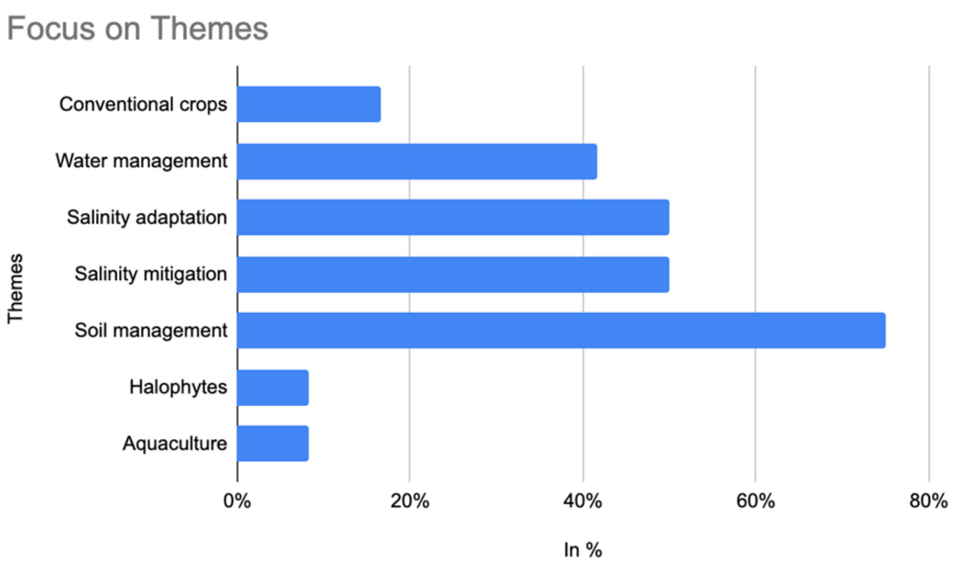

Figure 9 *Main themes addressed by the initiatives in South America.*

Initiatives from the Dutch governance landscape also focus on water management (66%), and soil management (34%). Initiatives here show a strong focus on salinity adaptation (76%), with a comparatively low focus on mitigation (28%). It is noteworthy that 97% of initiatives focus on the use of conventional crops for saline agriculture, while this topic is rather underrepresented among Argentinean initiatives. Similarly, the focus on halophytes and aquaculture remains relatively limited at 14% and 7% respectively.

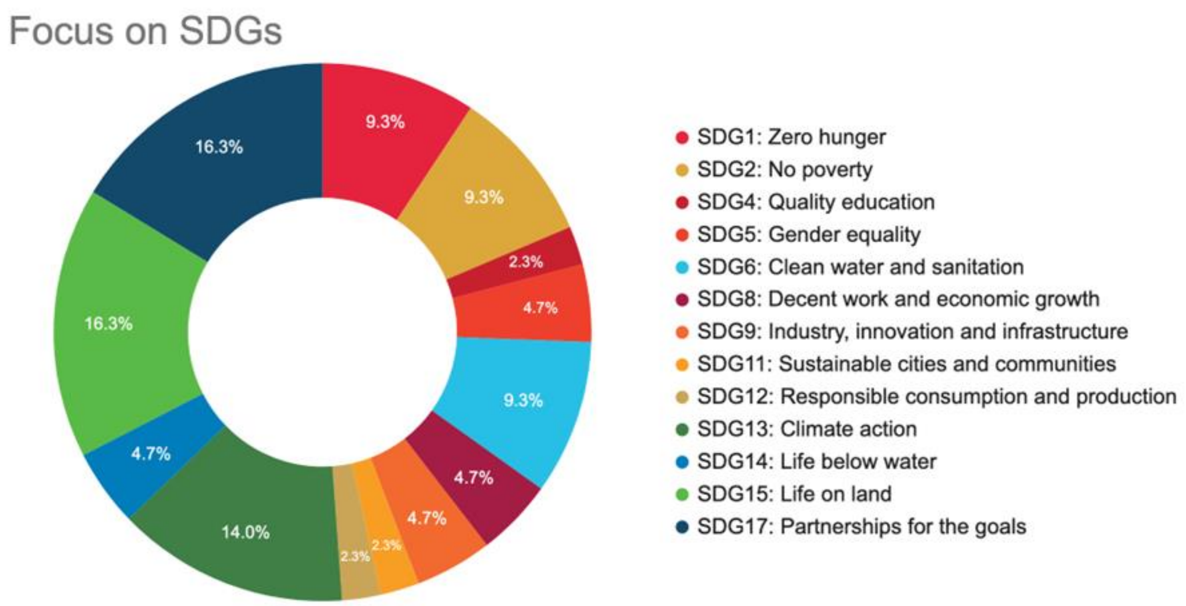

Figure 10 *Sustainable Development Goals addressed by the initiatives in South America.*

Finally, we looked at the SDGs addressed by the initiatives. SDG17 "Partnerships for the goals" and SDG 15 "Life on land" are the most commonly addressed goals in the Argentinian governance landscape. They are followed by SDG13 "Climate Action". SDG1 "Zero hunger", SDG 2: "No poverty", SDG 6 "Clean water and sanitation" are also important issue areas for the initiatives contributing to the United Nations' SDGs.

The picture looks quite similar for initiatives from the Dutch governance landscape. Here, SDGs, such as "Climate action", "Life on land", and "No poverty" are equally prioritised.

National initiatives and organisations
In analysing the governance landscape for salinity in Argentina, we not only identified internationally active initiatives, but also five national initiatives:

- Asociación Argentina de la Ciencia del Suelo (Argentine Soil Science Association).
- la Red Argentina de Salinidad (RAS) (Argentine Salinity Network).
- CREA - Asociación Argentina de Consorcios Regionales de Experimentación Agrícola (Argentine Association of Regional Consortia for Agricultural Experimentation).
- Addventure.
- Agroinnova America, Argentina.

Two of these initiatives are led by the private sector, one is a collaboration between the private sector and research, and one is a collaboration between public sector and research institutions. One of them is led by a civil society organisation. This indicates a different actor constellation than in the cases of the international cooperative initiatives. Most of these initiatives focus on information sharing and networking (80%), with one involved in operational activities and one in finance activities. They focus on soil management and conventional crops which also differs from international initiatives.

Additionally, four institutions are important players in the Argentinian salinity landscape. These include INTA - Instituto Nacional de Tecnología Agropecuaria (National Institute of Agricultural Technology), FAUBA (School of Agriculture of the University of Buenos Aires), Sustentia and Soil Research Institute. Most of these institutions belong to the public sector and salinity is one of many issue areas covered by them.

4.2 Reflections observed solutions with the FAO farmer guidelines

In Argentina, salinity management remains complex. As described in earlier sections in this Chapter, it is impacted by the bottom-up governance framework and regionally focused initiatives. To understand and reflect on the whole variety of observed solutions, Table 1 summarises the observed salinity management solutions in Argentina, their alignment with the FAO farmer guidelines, and key insights drawn from the mission (including stakeholder discussions and field observations).

The first observed solution was that public-sector-led initiatives, such as those by INTA, demonstrated strong involvement but that their national coordination could be improved, leading to partial alignment with FAO farmer guidelines. Moving on to the next solution, international cooperative efforts, involving organisations such as the FAO align well with FAO recommendations, as they emphasise knowledge exchange and partnerships. However, these initiatives are not systematically scaled or integrated into national frameworks, which limits their broader impact. Subsequent mentioned solution as the local farmer-led networks, such as the CREA model, showcase innovative, grassroots approaches to knowledge sharing. Yet, relatively little formal support and standardisation constrains their scalability and effectiveness. Similarly, the presented solutions of educational partnerships with institutions such as the University of Buenos Aires contribute valuable research but could improve on engagement with farmers to implement solutions effectively on the ground.

Finally, financial mechanisms for smallholder farmers, though present in limited forms, such as green loans, do not fully meet the needs of farmers in adopting sustainable salinity management practices. Stakeholder interviews revealed that these gaps in financial support could lead to incomplete adoption of technical solutions.

Table 1 *Reflection of observed salinity management governance solutions in Argentina with FAO farmer guidelines.*

Observed Current Solutions	Guideline Implementation	Notes
Public Sector-Led Initiatives for Salinity Management	Partially aligned: strong public sector involvement but limited coordination at the national level.	Initiatives like the INTA lead salinity efforts, but a cohesive national strategy is not sufficient yet.
International Cooperative Initiatives	Aligned with FAO farmer guidelines on fostering international partnerships.	Cooperative efforts include several actors, such as the FAO and the World Bank, with a focus on international salinity solutions.
Local Farmer-Led Knowledge Sharing	Partially implemented: informal farmer networks exist but lack standardisation and formal support.	Programs like CREA support collaboration, but there is relatively little support for smaller farmers and standardised knowledge exchange.
Educational Partnerships with Universities	Aligned in terms of promoting research but limited in practical applications for farmers.	Institutions like the University of Buenos Aires contribute valuable research but lack direct farmer engagement.
Limited Financial Mechanisms for Smallholder Farmers	Not fully implemented: some financing options exist but are not sufficient for broader adoption.	While financial institutions like Rabobank offer green loans, there is a relative limited framework for small-scale farmers to access these types of funds.

4.3 Unique governance solutions

International organisations active in Argentina

The Food and Agriculture Organization (FAO) of the United Nations, with a regional office in Buenos Aires, is actively engaged in initiatives in Argentina. The local FAO office collaborates closely with the Soil Doctors programme, which emphasises improving soil quality—particularly soil erosion—through satellite imaging and soil-related educational activities, including the "Suelos de mi País Soy" programme. While salinity is not addressed as a standalone project, it is incorporated within broader themes of biodiversity, water management, sustainable production, and land degradation. According to the FAO office, farmers commonly take soil samples for testing. However, low awareness regarding salinity management often hinders the proper application of these results. Key challenges include a lack of technical expertise, high costs, a tendency toward short-term planning, and issues, such as soil erosion. A potential opportunity for addressing these challenges lies in collaboration with the Global Environment Facility (GEF) Food System Program, particularly in the context of sustainable livestock management. Alongside this, the World Bank could also play a potential role here.

The World Bank, an international financial institution active in South America, primarily serves governmental clients, including that of Argentina. Key areas of focus for the institution include agriculture and biodiversity, with salinity emerging as a related concern in various projects, such as climate-smart agriculture initiatives in provinces, such as Río Negro and Córdoba. The World Bank aims to address saline lowlands, or bajos salinos, through a landscape approach, fostering innovation hubs at the provincial level to advance sustainable practices and regional solutions.

Farmer cooperation over competition

CREA is a non-governmental organisation founded by farmers in 1957 to address issues, such as soil erosion. CREA brings together agribusiness professionals who collaborate in small groups to tackle shared challenges. These groups operate across Argentina, Bolivia, Paraguay, Uruguay, and also in Georgia (Europe/Asia), typically consist of 8-12 members and follow a structured methodology. Monthly meetings are led by a volunteer president, supported by a technical advisor. Currently, over 2,100 agribusinesses participate in CREA, with 240 groups and more than 400 technical staff, alongside more than 700 active online members. CREA groups contribute between 5-10% of national agricultural output and are typically organised around specific environmental or social issues, with focus on operational efficiency within these areas. Groups with similar themes frequently connect, share insights, and collaborate with universities or local communities. While there is no specific group dedicated to addressing salinity, this issue often arises as a topic of discussion in many groups.

One key partner in the cooperation is the Faculty of Agronomy at the University of Buenos Aires, Argentina, which is well-known for leading projects, including the BISec platform — a tool designed for mapping deforestation. The faculty collaborates with the European Union on water salinisation research, particularly within initiatives, such as the Global Surface Water project, and with non-governmental organisations, like Solidaridad. Additionally, it contributes to evaluating salinity changes within the Buenos Aires Province. The faculty also serves as a hub for educational exchange programs, facilitating international student exchanges and academic collaboration.

Another key institution is INTA, which emphasises a strong interest in salinity from a fundamental research perspective. INTA supports joint projects with this focus, including a collaboration with the University of Córdoba, which specialises in salinity and nutritional stress and conducts experiments on sorghum germplasm. Noteworthy among these initiatives is Procesur, a national programme dedicated to advancing salinity-related technology. INTA also participates as a partner in the Agroinnova project.

Another notable farmer cooperative initiative is Aapresid, the Argentine Association of No-Tillage Producers (Asociación Argentina de Productores en Siembra Directa). Aapresid emphasises sustainable production through innovation, scientific advancement, and knowledge-sharing networks. Established in 1989, this association of producers centres on the adoption of new technologies and fosters collaboration among groups of farmers, extension agents, and R&D companies. Aapresid members also participate in organised working groups to enhance collective efforts. Additionally, Aapresid holds an annual national agri-tech conference, which serves as a platform for disseminating knowledge and promoting innovation.

America, a small town with a big potential for salinity research

Salinity presents a significant challenge in many Argentinian provinces, and the small town of America, in Buenos Aires Province, stands out for its proactive approach to addressing salinisation. America has fostered a public-private collaboration aimed at sustainable solutions and cooperation between rural and urban areas. Through this partnership, private land is made available for experimental trials, with municipal support to replicate research conducted at the University of Buenos Aires. This local approach operates independently of central government, increasing the municipality’s competitiveness. Unlike in the Netherlands, where the national government is more involved, Argentine municipalities often take the initiative due to limited federal support. Responding to political and economic challenges and the public’s concerns over agricultural chemicals (herbicides and pesticides), the municipality of America launched a project to explore innovative, sustainable solutions. Large local farmers contribute by providing land free of charge for these trials. The collaboration among farmers, government, and other stakeholders is open, with notable results such as increased crop yields over time.

While large-scale farmers often participate in CREA groups, smaller farmers tend to observe from the side-lines and learn from these initiatives. The Agroinnova project represents a further advancement, aiming to unify the insights of farmers, the public sector, and academia. Due to the lack of a nearby public university, Agroinnova also seeks to establish an educational centre in America to create opportunities for local young people.

5 Technical solutions to deal with salinity

As stated previously in Section 2.4, the key drivers of salinity in Las Pampas region in Argentina are topography (lowlands), shallow groundwater, land use change and climate change.

In this Chapter, we first discuss general solutions to deal with salinity. Then we reflect on observations and interactions with stakeholders in the case-study area. Lastly, we reflect on the technical solutions with the use of the FAO farmer guidelines.

5.1 Content analysis technical solutions salinity management

Argentina has implemented various technical strategies to manage salinity. Below, a few examples of these strategies found in the literature are presented:

1. **Crop variety adjustments**: To adapt to saline conditions, efforts have been focused on cultivating salt-tolerant crop varieties, particularly soybeans. Research on these adapted soybean cultivars has shown that they can endure mild to moderate salt stress, allowing for more stable yields under saline conditions (Chen et al., 2018).
2. **Optimising agronomic practices**: Adapting planting dates to synchronize with changing rainfall patterns can improve crop establishment and water use efficiency. This measure also serves as a buffer against seasonal droughts, and helps crops better withstand periods of water scarcity without compromising yields. This research is focused on Buenos Aires and emphasises that planting in Spring, blooming and fruiting in Summer, and harvesting in Autumn are crucial for summer crops. Similarly, the end of Autumn and the start of Winter coincide with the planting of winter wheat and other cereals. By adapting planting schedules to these seasonal precipitation trends, farmers can optimise water use and improve crop resilience (Scarpati and Capriolo, 2020).
3. **Irrigation systems**: In regions vulnerable to fluctuating river flows and reduced glacial melt, irrigation infrastructure plays a crucial role. Installing irrigation systems can help secure water access during dry periods, reducing the risk of crop losses, especially in areas that depend on seasonal river flow. Increased investment, coupled with insurance and credit mechanisms, is recommended to support smallholders in adopting climate-resilient irrigation methods and encourage participation in pilot adaptation projects (World Bank Group, 2021).
4. **Capacity building and knowledge dissemination**: Argentina has taken steps to raise awareness within its agricultural sector regarding climate impacts on salinisation. Initiatives include improved water monitoring systems, promoting climate-resilient crops, and offering technical assistance through national extension services to aid farmers in adapting production practices in-line with climate trends (OECD, 2024). This capacity-building approach supports the long-term adoption of climate-sensitive practices at the regional level.
5. **Bio-drainage**: In areas with high water-tables, bio-drainage has shown promise as an alternative to engineered drainage systems. This method involves planting deep-rooted tree species that help stabilize groundwater levels by absorbing excess water, which reduces upward salt movement. Though effective, bio-drainage can have drawbacks, such as salt accumulation in the root zone and increased groundwater use by trees, which can alter the local water balance (Singh, 2021; Nosetto et al., 2013).
6. **Rainwater harvesting and soil coverage with native species**: Near Buenos Aires, small-scale rainwater harvesting systems have been promoted to manage soil salinity. These systems capture rainwater to help flush salts from the soil profile and promote soil coverage with native plant species. Native species, with extensive root systems, enhance soil porosity, reducing salt rise by limiting evaporation and increasing infiltration rates. This approach not only supports salinity management but also contributes to improved soil health and crop productivity (INTA, 2022).

5.2 Observations of the case study area

As described in Chapter 2, the Agroinnova site has served as a case study. Technical solutions for salinity management in the region vary significantly, influenced by the severity of salinity issues and the level of knowledge among the farmers engaged. Responses to salinity ranged from leaving affected areas to be restored to natural vegetation. In areas with extensive pastures for livestock, many farmers have chosen to let the land transition back to natural vegetation, allowing low intensity grazing, rather than intervening directly. On larger commercial arable farms, however, there was a strong focus on restoring soil health. In these cases, salt-tolerant native plants were introduced, and specific management practices, such as reduced ploughing and rolling, were used to promote plant growth. These methods allow excess water to evaporate over time, gradually reducing soil salinity and ultimately regenerating the land for agricultural use. (See Annex 4 for field impression photos).

The urgency with which farmers address salinity often depends on how much of their total land area is affected. During field visits, the observation was that commercial farms ranged in size from a few thousands to over 40,000 acres. Within these large fields saline-affected patches were relatively small, usually around 1,000 m² in size. For instance, in a 300-acre field (1.2×10^6 m²), a few salt-affected patches with a total area of roughly 10,000 m² would only entail about 0.8% of the total field area. This relatively small proportion influences the farmers' perceived urgency in addressing salinity.

Many agricultural systems in the region have shifted from annual crops, which require 900-1000mm of water per year, to Summer crops with a water demand of only 500-600 mm per year. This reduction in water use has a direct impact on the recharge of the water-table, which is closely tied to annual precipitation. To manage this balance, one widely implemented strategy is the use of cover crops. Among other benefits, cover crops increase water consumption, effectively lowering the water-table and keeping it at a manageable distance from the soil surface, thus, reducing the risk associated with a high water-table.

An additional observation relates to farms located in La Pampa Ondulada, a region characterised by undulating terrain. In these areas, certain fields are noticeably lower than others, resulting in a shallower water-table. Salinity and waterlogging are more pronounced in these low-lying fields, where rising water-tables heighten these stresses. To mitigate these issues, farmers often plant maize in the lower areas and soybean in the higher sections, as they consider maize to be more tolerant to such conditions. Interestingly, although literature suggests maize is more sensitive to salinity than soybean, the farmers' experiences in these conditions have led them to prefer maize for these more challenging areas (Salt Doctors, 2024).

Soil analysis conducted by the Salt Doctors on one of these farms, gives more insights on potential yield loss factors, revealing soil sodicity as a possible cause of structural degradation in deeper soil layers. In the wheat and maize fields, where irregular growth was observed, results showed no significant salt accumulation at the sampled depths during the end of winter, following a rainy season. However, the high pH levels detected suggest compromised soil structure, often leading to poor permeability and limited aeration—conditions conducive to waterlogging. Compacted soil restricts water and air movement through the soil profile, limiting root growth and the availability of essential nutrients. This ultimately leads to stunted plants and lower yields (Salt Doctors, 2024).

5.3 Reflection observations technical solutions with FAO farmer guidelines

Table 2 displays the reflection of implemented technical salinity solutions in Argentina with the FAO farmer guidelines. The first presented solution is the adaptation of crops to salt-tolerant varieties, which partially aligns with FAO farmer guidelines. Argentina has focused on increasing the salt tolerance of widely cultivated crops, such as soybean. However, full exploration of halophytes—plants naturally adapted to saline conditions—has not yet been (fully) initiated, leaving room for further innovation. The optimisation of planting dates has been fully implemented and aligns with FAO guideline. The next solution presented solution is the use of cover crops for managing water-tables. Cover crops increase water uptake, thereby supporting maintain water-tables at manageable levels and reducing salinity risks in the root zone. However, broader adoption of this practice is limited by limited financial and technical support. Likewise, implementation of irrigation systems remains limited and is mainly confined to high-value crops in specific regions. Expanding irrigation infrastructure would require significant investment and policy support to benefit more farmers.

Also mentioned is bio-drainage using deep-rooted tree species show promise but are only partially aligned with FAO farmer guidelines. While these trees help lower groundwater levels and manage salinity, they also pose risks such as salt accumulation in root zones and different local water balances. Moving to rainwater harvesting systems, mainly implemented near Buenos Aires, are another promising approach to flush salts from the soil and support native vegetation. However, their use remains limited due lack of widespread adoption and investment.

Finally, soil amendments, such as gypsum and organic materials, are selectively applied to improve soil structure in saline-affected areas. While these amendments could be effective, their broader use is limited by financial support and technical guidance. Farmers often rely on natural vegetation to restore soil health but are unsure on how long affected plots should remain under such conditions. This uncertainty highlights the need for research to refine guidelines for sustainable soil management.

Field observations show that agronomists carry equipment, such as EC meters and soil sampling tools, but the varying application of protocols limits the systematic monitoring of salinity. Furthermore, large-scale infrastructure, such as drainage systems, is not observed, leaving waterlogging and high groundwater-tables as challenges.

Table 2 *Reflection of observed salinity management technical solutions in Argentina with FAO farmer guidelines.*

Observed Current Solutions	Guideline Implementation	Notes
Adaptation of crops to salt-tolerant varieties	Partial implementation: focus on salt-tolerant soybean and local varieties.	Ongoing adaptation efforts to increase salt tolerance in existing crops like soybean. Full exploration of halophytes not yet initiated (or observed).
Optimisation of planting dates	Aligned with FAO recommendations.	Adjusting planting dates to match evolving rainfall patterns helps mitigate drought risks and supports crop resilience.
Use of cover crops to manage water-table	Partially implemented as a moisture control measure.	Cover crops increase water uptake, keeping the water-table at a manageable level and reducing salinity risk in the root zone.
Implementation of irrigation systems in vulnerable areas	Limited implementation: region-specific irrigation support.	Limited to areas with high-value crops; broader irrigation expansion would require more financial and technical support.
Bio-drainage with deep-rooted trees	Experimental, partially aligned.	Bio-drainage with trees shows promise but has risks, including potential salt accumulation in root zones and altered water balance.
Rainwater harvesting systems	Limited implementation near Buenos Aires.	Rainwater harvesting helps flush salts from the soil and supports native vegetation, improving porosity and reducing salt accumulation.
Use of soil amendments improvement	Limited implementation: gypsum and organic amendments recommended.	Soil amendments like gypsum are applied selectively to improve structure in saline-affected soils, though broader use requires further support. Look at natural occurring vegetation growth, from there you need to come up with a plan on what to do, where is the salt, how is the groundwater-table. It is unclear how long a salinity plot needs to remain under natural vegetation. One year, two years, three years. Now, this may not be so much of an issue, but when the international market will gain traction again, farmers will want to use all their fields to full potential.

5.4 Stakeholder interactions in the case study area

The observations already show that salinity is an increasingly pressing matter in the region, with visible salt accumulation contributing to a decline in crop productivity. The shift from traditional land uses to more intensive farming practices has increased the need for effective salinity management strategies. Current efforts to monitor salinity are relatively limited. These involve the use of salinometers and sporadic soil sampling. However, there are no standardised or widespread approaches to track and mitigate salinity on a larger scale. Through discussions, it became clear that although protocols for regular soil sampling exist, their implementation is either inconsistent, or do not always follow the protocol required to document and understand valuable insights. Without adequate data, it becomes challenging to implement the envisioned opportunities.

In general, the farmers' main approach to improving soil fertility in the saline-prone areas involves allowing the natural vegetation to grow for one to two years. This vegetation is often cut, incorporated into the soil, and used to enhance its structure. Once the soil shows signs of improvement, more salt-tolerant species, such as Agropyron or Panicum spp. are introduced in lower areas with higher salinity (locally called 'bajos salinos'), while barley, wheat, or sorghum are planted in the higher areas (locally called 'lomas'). The crops are rotated with the natural vegetation, which also serves as an indicator of the soil's salinity levels. This rotation aims to restore the most affected soils and maintain a lower water-table. On this farm, more specifically, farmers have applied this approach to over 2,000 hectares. While the levels of salinity and the results have varied across different areas, the overall success of this method has encouraged them to continue, as it has proven to be quite effective.

Next to the soil management, water management is particularly challenging. This is because most farms are rain-fed, with flat topography that could restrict natural drainage. Improving drainage and water management infrastructure could significantly support in reducing salinity. It is indicated by stakeholders that governmental support could play an important role in scaling up best practices across the region by funding monitoring initiatives and promoting sustainable water management.

Reflecting on a particular example, the Salt Doctors advised a local farmer about salinity management on his farm (Salt Doctors, 2024). This farmer, primarily focused on cattle grazing, shared his experiences with managing salinity on his farm. Over the past years, he has faced challenges with soil salinity, which led him to abandon the cultivation of common crops in favour of exploring more salt-tolerant forage species like 'tall wheatgrass (*Agropyron elongatum*). However, despite these attempts, he found limited success with cultivation and ultimately decided to let natural vegetation reclaim the land. Among the plant species that have thrived in these saline-prone areas is 'pelo de chancho' (*Distichlis spicata)*. This grass is particularly resilient to saline conditions and provides valuable forage in environments where other species struggle to survive.

In summary, farmers acknowledge the presence of salinity issues, some actively monitor or fully assess the extent of soil damage. In many cases, they adopt partial mitigation practices, such as using cover crops in affected zones to deal with salinity. Typically, these salt-affected areas represent a small proportion of their fields.

6 Scaling and adapting to Dutch context

This Chapter reflects on whether and how the previously identified solutions can be scaled and adapted to other contexts, such as the Netherlands. It begins with a brief reflection on the requirements of scaling, followed by an analysis of the different types of solutions and their scaling potential. The focus then shifts to exploring possibilities for adapting these solutions to new contexts, using the FAO farmer guidelines as a guiding principle.

Recent studies highlight that successful upscaling of adaptation strategies require a multidisciplinary approach (Qiu et al., 2024) (Deolu-Ajayi et al., forthcoming). Key factors for effective scaling in this context, include maintaining diversity, ensuring connectivity, addressing spatial synergies and trade-offs, managing nonlinearity, and embracing scale and polycentricity. Parmentier (2014) identifies critical challenges for scaling agroecological practices, such as overcoming ideological barriers for political recognition, establishing farmer-to-farmer knowledge-sharing networks, supporting supportive public policies, and specifically empowering women to enhance food governance. Additionally, a study by the U.S Agency for International Development (USAID) on agricultural technology scaling highlights that effective scaling requires more than just technology implementation. It involves a sustained focus on broader contextual factors and long-term commitment, often extending beyond the timeframe of individual projects (USAID, 2014).

Focusing on the salinisation context and scaling, the causes and impacts of salinity differ significantly between Argentina and the Netherlands. As previously highlighted, salinity in the Pampas region of Argentina primarily origins from the natural weathering of rocks and minerals, as well as ancient marine sediments and land-use changes enhance human increased salinity.

Salinity in the Netherlands is largely a coastal issue, driven by processes, such as seepage and flood-induced salinisation. However, this does not exclude the influence of other salinity types. The scale and impact of salinity in the two countries also differ. Argentina’s large-scale farms contrast sharply with the smaller, more intensively managed farms in the Netherlands, resulting in different governance structures and management practices. Adapting solutions from one context to the other requires some consideration of these differences. Table 3 presents the solutions implemented in Argentina, highlighting the most appropriate scaling approaches for each. Table 3 further outlines how these solutions can be adapted to the Dutch context, considering differences in environmental, agricultural, and governance frameworks.

Overall, financial support is essential for scaling saline agriculture strategies, particularly for projects that require sustained investment. Rabobank, a Dutch bank with branches in Argentina and several other countries, has prioritised rural farming, sustainable agriculture, and biodiversity. Their Future Farmers Council facilitates exchanges between Dutch and international farmers, within which sustainable practices and adaptation strategies are discussed. In Argentina, Rabobank addresses salinity primarily through water management and irrigation solutions. The bank supports sustainable agriculture through various financial products, such as green loans, sustainability-linked loans, and the Agri-Fi fund—a partnership with the UN aimed at supporting smallholders. The Dutch branch of Rabobank uses specific benchmarks, including the National Inventory, Paris Agreement standards, and the Carbon Calculator Platform, when assessing loan applications.

Overall, reflections on scaling saline adaptation strategies in the Netherlands present challenges, particularly in terms of required investments and uneven stakeholder benefits. Dressler et al. (2022) show that scaling ecosystem restoration, such as coastal restoration, depends on confidence in the technical, economic, and management frameworks needed to overcome fragmented local efforts. Given the high population density and intensive land use, scaling solutions in saline agriculture must be adaptive, synergistic, and integrated with existing agricultural activities, while also aligning with national policies.

Table 3 shows the identified solutions and is focused on whether the solutions can be adapted and scaled to the Netherlands context. In the first column, a summary of all the identified solutions from Chapters 5 and 6 are repeated. In column three, the most likely scaling type is presented based on the concepts presented in the methodology. In column 4, the rationale for the scaling is presented.

When considering the potential for the Netherlands to adopt solutions already implemented in Argentina, three of these solutions stand out as particularly relevant and easy to learn from: optimising planting dates, international cooperative initiatives, and educational partnerships with universities (dark green). Additionally, solutions marked as light green in Table 3 represent practices that have not yet been fully implemented in Argentina, according to FAO farmer guidelines, but hold significant potential for adaptation and scaling in the Netherlands. These solutions offer opportunities for mutual learning and include the adoption of salt-tolerant crop varieties, the use of cover crops for water-table management, rainwater harvesting, soil amendments to improve structural integrity, public-sector-led salinity initiatives, and local farmer-led knowledge-sharing networks.

Potential scaling and adaptation strategies in the Netherlands might vary depending upon the region. For instance, on the Dutch island, Terschelling, where livestock production is important, saline agriculture could support local practices by promoting salt-tolerant forage varieties, halophyte cultivation, and desalination for freshwater. In areas such as Texel and Zeeland, where saline agriculture is already practiced, methods such as using salt-tolerant crops, cultivating halophytes, and installing drainage systems are under investigation. Experimental uses of halophytes as animal feed are limited due to high salt content, but halophytes offer potential for land remediation, biofuel production, and pharmaceuticals (Mann et al., 2023; Sarath et al., 2021).

Table 3 *Identified solutions, scaling types and adaptation potential for The Netherlands.*

Solution and implementation in Argentina	Type of Solution	Scaling Type and Rationale Scaling	Potential Suitability for Dutch Context
Adaptation of Crops to Salt-Tolerant Varieties	Technical	Horizontal Scaling. Transfer of salt-tolerant varieties from one farmer to another or from greenhouse to field scale allows replication without major changes.	Suitable: The Netherlands could benefit from salt-tolerant varieties, especially in coastal and saline-affected areas. Horizontal scaling among Dutch farms is feasible.
Optimisation of Planting Dates	Technical	Horizontal and Vertical Scaling. Can be implemented across farms (horizontal) but also supports from policy support for broader adaptation strategies to climate variability.	Suitable: Adjusting planting dates based on rainfall patterns would be useful, especially with climate variability. Policy support (vertical scaling) would enhance adoption.
Use of Cover Crops for Water-table Control	Technical	Horizontal Scaling. Cover crops for water management can be adopted across farms in similar conditions, mitigating salinity risk.	Suitable: Dutch farms could implement cover crops to control water-tables and to deal with salinity. This can be scaled horizontally across regions.
Irrigation Systems in Vulnerable Areas	Technical	Vertical and Functional Scaling. Requires policy and financial support (vertical) and can be integrated with rainwater harvesting and other water management activities.	Partially Suitable: While irrigation systems could help, Dutch water management systems are advanced. However, specific targeted irrigation for drought periods could be functional.
Bio-Drainage using Deep-Rooted Trees	Technical	Functional Scaling. Serves multiple purposes: water-table management, soil health improvement, and aligns with environmental sustainability goals.	Possibly Suitable: Bio-drainage might be used selectively in low-lying Dutch areas, but careful management would be needed to avoid unintended salinity shifts.
Rainwater Harvesting	Technical	Functional and Horizontal Scaling. Can be replicated across farms (horizontal) and supports land restoration and sustainability (functional).	Suitable: This would be useful, particularly in areas where salinity control and soil health are priorities and can be implemented on individual farms or cooperatives.
Soil Amendments for Structural Improvement	Technical	Vertical and Functional Scaling. Requires policy and financial support for broader use; integrates well with soil restoration practices for sustainable agriculture.	Suitable: Soil amendments like gypsum are already used, and could be expanded, particularly with policy support. Functional scaling with other soil health practices is ideal.

Solution and implementation in Argentina	Type of Solution	Scaling Type and Rationale Scaling	Potential Suitability for Dutch Context
Public-Sector Led Salinity Initiatives	Governance	Vertical Scaling, Led by Government; could be integrated into national policy frameworks to ensure regional support and coordination.	Suitable: Expanding public-sector initiatives would align well with Dutch policies and provide consistent support across saline-prone regions.
International Cooperative Initiatives	Governance	Horizontal and Functional Scaling. Allows for knowledge exchange (horizontal) and integrates broader environmental goals across regions (functional).	Suitable: Collaborations with international bodies would allow knowledge exchange and reinforce the Netherlands' role in global water and salinity management efforts.
Local Farmer-Led Knowledge Sharing	Governance	Horizontal Scaling. Informal networks of farmers can expand locally, enabling more farmers to access practical solutions without requiring policy changes.	Suitable: Dutch farmers could benefit from expanded farmer networks for sharing salinity solutions, potentially replicating models like the CREA network in Argentina.
Educational Partnerships with Universities	Governance	Vertical and Functional Scaling, Contributes research and innovation; could be formalised into national frameworks and supports community-level education.	Suitable: Universities could provide research-based solutions, and partnerships could ensure knowledge transfer directly to farmers, especially on technical salinity solutions.
Limited Financial Mechanisms for Smallholder Farmers	Governance	Vertical Scaling, expanding financial support via policy or financial institutions would improve access for smallholders to resources for salinity management.	Possibly Suitable: Expanding financial support through Dutch policies and institutions would be valuable, though adapted for the smaller scale of Dutch farms.

7 Conclusions and recommendations

This Chapter synthesises key findings on governance and technical solutions for salinity management. It draws lessons from Argentina and explores their applicability and scalability to the Dutch context. This interdisciplinary approach facilitated the identification of scalable solutions and important governance dynamics. The FAO farmer guidelines have proven to be a useful framework for reflecting on and translating salinity management practices to the Dutch context. These guidelines effectively support the process of understanding and adapting Argentina's context-specific solutions to align with the environmental, social, and institutional dynamics of the Netherlands.

To reflect on the specific governance solutions, addressing salinity requires sustained multi-stakeholder investment, from farmers and local governments to private sector actors and academic institutions. Specifically, by combining Argentina's dynamic, grassroots approaches with the Netherlands' advanced governance and infrastructure, a robust framework for saline agriculture could be developed. The transition to saline agriculture requires significant long-term investment from various stakeholders, including farmers, provincial bodies, companies, water authorities, and national ministries. The main differences and similarities among two governance landscapes can be summarised in the following points:

- **Strong public actors**: The Argentinian governance landscape is dominated by public actors cooperating with companies and NGOs.
- **Balanced governance functions**: The governance functions of ICIs in Argentina and South America are more evenly distributed with higher percentage of initiatives focused on financing and setting standards in the field than Dutch and European ICIs.
- **Focus on soil salinity**: Argentinian initiatives are more focused on the soil salinity, mitigation and adaptation, whereas the Dutch initiatives are more interested in water salinity and conventional crops.
- **Importance of partnerships**: Among Argentinian and South American ICIs. There is a strong focus on SDG17 "Partnerships for the goals" and SDG 15 "Life on land" among the initiatives. This is also reflected in strong local- and regional farmer networks.

Argentina's grassroots, farmer-led governance supports local initiatives, such as the CREA network, which facilitates farmer-to-farmer learning and innovation. These informal yet structured collaborations demonstrate how farmers can self-organise to tackle shared challenges such as salinity. Public institutions, such as INTA play a valuable role in providing research support. However, their impact could be further enhanced through more national coordination. In contrast, Dutch governance offers institutionalised policy frameworks and stronger state involvement. However, the Netherlands could benefit from adopting Argentina's bottom-up, community-led approaches, particularly in regions where local adaptation and innovation are critical. For example, supporting and increasing cooperative models like CREA could increase Dutch farmers' capacity to address salinity issues at the local level.

Regarding technical solutions, Argentina uses a variety of technical measures that have shown promise under its specific conditions:

- **Salt-tolerant crops**: Efforts to develop and cultivate salt-tolerant soybean and other crops address moderate salinity stress, providing resilience in affected areas.
- **Cover crops and planting dates**: Adjusting crop calendars and introducing cover crops help manage water-tables and reduce salinity through enhanced soil structure and moisture regulation.
- **Bio-drainage and rainwater harvesting**: Deep-rooted species like *Eucalyptus spp.* are planted to lower the water-table, while small-scale rainwater harvesting systems flush salts from the soil profile.
- **Localised soil amendments**: Gypsum and organic amendments are selectively applied to improve soil structure and mitigate sodicity.

Table 3 provides an overview of the identified solutions in Argentina, which is focused on their scaling potential and applicability to the Netherlands. Scaling strategies are assessed based on horizontal, vertical, and functional scaling types. The insights from Table 3 highlight the following points:

- **Horizontal Scaling:** Solutions such as salt-tolerant crop varieties, cover crops, and adjusted planting dates can be directly transferred to similar contexts in the Netherlands, particularly in coastal regions prone to salinity. For example, the introduction of salt-tolerant forage crops for livestock.
- **Vertical Scaling:** Some practices, such as rainwater harvesting and soil amendments, require policy and financial support to enable broader adoption. These could be integrated into national frameworks to ensure alignment with Dutch water management systems and agricultural policies.
- **Functional Scaling:** Multifunctional solutions, such as bio-drainage and halophyte cultivation, align with broader sustainability goals, including land remediation. While these require careful adaptation to Dutch conditions, the multifunctionality offers additional incentives for adoption.

Mutual learning between Argentina and the Netherlands

For learning together on the topic of saline agriculture, establishing and further developing mutual learning platforms where different stakeholders (e.g. policy, practitioners, financial institutions) is important. A local innovation hub could serve as a continuous learning mechanism, connecting these diverse stakeholders and enabling the exchange of experiences. Contextual factors, such as economic conditions and policy influences (e.g. EU regulations), play an important role in shaping the success of such collaborations. For example, Argentina’s bottom-up governance approach, driven by limited central policy steering, provides valuable insights for fostering grassroots innovation in the Netherlands. Key recommendations to facilitate mutual learning include:

- **Support and enhance farmer networks**: Support local knowledge-sharing platforms, inspired by Argentina’s CREA, to further develop Dutch farmers networks with practical, region-specific salinity solutions with a focus on a ‘bottom-up’ approach.
- **Policy support and financial incentives**: Enhance subsidies for adoption of saline agriculture practices, including financial supporting for supporting healthy soils, salt-tolerant crop varieties, cover crops, and (bio)-drainage systems.
- **Integrate saline agriculture with market innovations**: Promote saline products, such as halophyte-based foods, in both domestic and international markets. Branding these products for their potential ecological benefits could support a viable business case.
- **Invest in monitoring and research**: Further develop a comprehensive salinity monitoring framework using satellite and on-ground data, building on Argentina’s experience with INTA’s soil and water research initiatives.

The proposed innovation hub can also act as a starting point for scaling solutions to other regions and stakeholders, supporting interdisciplinary collaboration and continuous knowledge exchange. In this way the knowledge can be exchanged and further scaled, adapted also to other contexts.

In conclusion, addressing salinity challenges requires an integrated approach that combines governance, technical solutions, and mutual learning between diverse stakeholders. By synthesising lessons from Argentina and reflecting on the FAO farmer guidelines, this report highlights possibilities to adapt and scale salinity management practices to the Dutch context. Further underlining Argentina’s bottom-up, farmer-driven initiatives within the Netherlands’ institutionalised governance approach can create a balanced and dynamic approach to deal with salinity. Establishing an innovation hub for saline agriculture will not only facilitate interdisciplinary collaboration but also ensure the continuous adaptation and exchange of knowledge. By fostering mutual learning, aligning governance structures, and supporting the scaling of practical solutions, both Argentina and the Netherlands can continue building resilient, sustainable agricultural systems that address the global challenge of salinisation.

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Annex 1 Semi-structured interviews

General Information

1. Can you tell us about your farm?
    a. Size, location, and type of crops grown.
    b. Duration of farming in this area.

Understanding and Awareness of Salinity

2. Are you aware of salinity issues affecting your farm?
    a. How did you become aware of these issues?
    b. What are the visible signs of salinity you have noticed (e.g. white crust on the soil, poor plant growth)?

Soil Management Practices

3. How do you assess soil salinity on your farm?
    a. Do you use any specific tools or methods to measure soil salinity (e.g. visual inspection, salinometers, laboratory tests)?
4. What soil management practices do you use to mitigate salinity?
    a. Practices such as soil amendments (e.g. gypsum, organic matter), land leveling, tillage, or subsoiling.
    b. How effective do you find these practices?

Water Management Practices

5. How do you manage irrigation in salt-affected areas?
    a. Type of irrigation systems used (e.g. drip, sprinkler, subsurface).
    b. Frequency and amount of water applied.
    c. Use of leaching to manage salinity levels.
6. Do you have any drainage systems in place to manage saline water?
    a. Types of drainage systems (e.g. surface, subsurface, bio-drainage).
    b. Effectiveness of these systems in managing salinity.

Crop Management Practices

7. What types of crops do you grow in saline-affected areas?
    a. Are there specific crops that you find more tolerant to salinity?
    b. Do you practice crop rotation or use specific cropping patterns to manage soil health?
8. Do you use any special techniques for planting and cultivating crops in saline soils?
    a. Techniques such as seedbed shaping, salt scraping, or the use of salt-tolerant varieties.

Community and Knowledge Sharing

9. Do you participate in any local groups or networks that address salinity issues?
    a. How do you share knowledge and experiences with other farmers?
    b. Have you received any training or attended workshops on managing salinity?

Government and Private Sector Support

10. What kind of support do you receive from Government or private sector initiatives?
    a. Availability of subsidies, technical assistance, or advisory services.
    b. How effective do you find this support in managing salinity issues?

Challenges and Opportunities

11. What are the main challenges you face in managing soil and water salinity?
    a. Technical, financial, or knowledge-based challenges.
12. What opportunities do you see for improving salinity management on your farm?
    a. Innovations, training, or new practices you would like to adopt.

Closing

Is there anything else you would like to share about your experience with managing salinity on your farm?

Annex 2 List of terms used for Internet search

Internet search areas and terms	Argentina, South America, Latin America, food insecurity, food production, food access*, food availab*, salinity tolerance, saltwater agriculture, soil salinity, irrigation with saline water, saline crop production, salinity management, soil improvement, sustainable agriculture, soil fertility, soil conservation, drought resistance, crop rotation, land reclamation, water use efficiency, agroforestry, agricultural diversification, salinity, saline agriculture.

* To search for multiple forms of this word.

Annex 3 List of keywords for semi-automated content analysis

Strong keywords	**Biosaline agriculture, brack*, coastal agriculture, halophyte*, saline, saline agriculture, salini*, salt-affected*, salt tolerant, sodic soil***
Weak keywords	Weak keywords: Adapt*, soil*; aquaculture*, benefit*, biodiversity, climate change, coast*, crop*, cultivat*, desertification, drought*, ecosystem*, farm*, finan*, flood*, food, food security, food sustainability, irrigat*, land degradation, degradation, landscape restor*, mitigat*, partnership*, polic*, resilien*, sea level, sea level rise, soil management, sustainab*, upscaling, water management, water quality, watersecurity, yield*

* To search for multiple forms of this word.

Annex 4 Photo Impressions

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