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Salinity in African Countries: From Local Challenges to Global Solutions

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Salinity in African Countries: From Local Challenges to Global Solutions

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Executive summary

Salinisation of soil and groundwater is a major challenge for agriculture and a pervasive problem throughout the sub-Saharan region. Exacerbated by climate change, salinisation has profound impacts on the region's environment, economy, and people.

Global cost estimates from 2014 indicate that the annual economic losses due to salt-affected areas amount to US$27.3 billion. In Africa, approximately 80 million hectares are affected, with up to 68.8 million hectares in sub-Saharan Africa. Next to considerable economic losses, salinisation also impacts local livelihoods, food security and migration patterns in affected regions.

These challenges are particularly important in the context of sub-Saharan countries, where agriculture plays an important role not only in ensuring food security, but also in shaping livelihoods, fostering development, and driving economic growth. As the population grows, so does the demand for land, water, and food. The escalating needs for these essential resources, compounded by the challenge of salinisation, underscores the urgent call for swift and effective solutions. However, knowledge of the extent and impacts of salinisation remain fragmented and the costs associated with salinisation do not appear to be corresponding with the investments of development projects. To address this challenge, this report synthesises the current state of scientific knowledge on the problem of groundwater and soil salinisation in sub-Saharan Africa, providing a comprehensive overview across 12 countries selected by the Netherlands Enterprise Agency (RVO). The impact of salinisation on agriculture and food security in these nations is assessed based on interviews with experts and extension officers. To provide an overview of the governance landscape of saline agriculture, international cooperative initiatives are analysed based on several characteristics.

This report highlights three key findings. First, the results show that there are significant disparities in the availability and quality of scientific knowledge of groundwater and soil salinisation in sub-Saharan countries. Based on current research, salinisation is prevalent in coastal areas and river deltas. Reasons for this include seawater intrusion and seasonal variations in the salinity fronts of rivers, depending on the wet and dry seasons. This is consistent with the availability and distribution of knowledge: coastal countries are relatively well studied, while more central countries lack comprehensive analyses. However, there are some outliers, such as Ethiopia, where interviews also revealed high salinity in inland areas. In addition, the interviews highlighted common problems of data unavailability and inconsistency, which pose challenges for knowledge provision and dissemination. Therefore, the prevalence of salinity in coastal areas and river deltas may stand out due to the lack of data for arid and semi-arid inland areas.

Second, the impact assessment revealed that salinisation has far-reaching economic, environmental, social, and cultural impacts in affected countries. The most severe impacts are the considerable loss of crop yields and productive agricultural land negatively affecting communities' livelihoods and food security. Other common, and partly linked challenges are effects on water quality and biodiversity, rise in poverty and stakeholder conflicts and social tensions due to less available land.

Third, although international cooperative initiatives are active in all 12 focus countries, the number of initiatives per country varies considerably. While the initiatives are mainly

involved in operational, information sharing and networking functions, which are crucial for sharing knowledge and implementing pilot projects, a stronger commitment to funding, standards and long-term commitments is essential for widespread and effective implementation of adaptation strategies. Policies directly addressing salinisation are scarce in the focus countries. However, salinity is relatively often addressed in the context of other policies related to soil, water, biodiversity, and land degradation. It became clear that there is a considerable gap between the investment needed to prevent the enormous economic losses caused by salinisation in this region and the funds available to finance such initiatives. This needs to be taken into account if salinisation is to be properly addressed to secure smallholder incomes at the local level and ensure economic growth and development at the national level.

Based on these finding, we formulate the following recommendations for policy and practice:

- Allocate resources to conduct studies on groundwater and soil salinisation in sub-Saharan countries, where knowledge gaps currently exist.
- Establish systemic regional monitoring and evaluation programs aimed at developing and understanding salinisation patterns and impacts.
- Foster collaboration and information sharing among sub-Saharan countries, particularly those countries experiencing high salinisation, such as countries with coastal areas and river deltas or countries with high arid salinisation.
- Encourage the adoption of saline agriculture practices as a viable adaptation strategy in affected regions by providing training and support for farmers and stimulate the Dutch knowledge institutions and private sector to share their expertise.
- Encourage governmental bodies to integrate the problem and formulate policies addressing salinisation in existing agriculture, water, and climate policies.
- Mobilise funds from international organisations, governmental bodies, and private sectors such as Green Climate Fund to bridge the gap between costs of salinisation and required investments.
- Involve more civil society and private actors in the initiatives to represent a wider range of stakeholders and variety of topics, including water, food, and biodiversity nexus.
- Raise awareness about adverse effects of improper water management practices that can increase salinity in the future.

Contents

List of abbreviations

EC	Electrical Conductivity
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organisation of the United Nations
ICIs	International Cooperative Initiatives
MENA	Middle East and North Africa
NASMP	The National Agricultural Soil Management Policy 2020
NBSAP	National Biodiversity Strategy and Action Plan
NIP	National Irrigation Policy 2017
SDGs	Sustainable Development Goals
UNCCD	United Nations Convention to Combat Desertification
CBD	Convention on Biological Diversity

List of figures

List of tables

1 Introduction

In recent years, climate science has clearly warned of the severe physical and socio-economic impacts of climate change, which threaten to escalate without more ambitious action (UNCCC, 2022). Sub-Saharan Africa is particularly anticipated to bear a disproportionately adverse impact, stemming not only from projected temperature increases and insufficient rainfall but also due to the vulnerability of its population (Thompson *et al.*, 2010). In this socio-climatic context, climate change results in reduced crop productivity, land degradation, and elevated market prices, thereby negatively affecting livelihoods and contributing to increased malnutrition (Bain *et al.*, 2013; Thompson *et al.*, 2010). The repercussions on food security are thus expected to be substantial. At the juncture of food security and climate change, salinisation emerges as a noteworthy concern. Implementing adaptation strategies could serve as a way to alleviate the severity of food insecurity throughout the entire region (Connolly-Boutin & Smit, 2016). Equally important is the implementation of mitigation strategies to avoid worsening the effects of climate change. While adaptation involves adjusting agronomic practices to utilise saline soils and reduce crop vulnerability to salt stress, mitigation involves reducing soil salinity through technologies such as improved water management and soil improvement (Tedeschi *et al.*, 2023). A combined approach of adaptation and mitigation to salinisation is therefore recommended (Zaman *et al.*, 2018).

Salinisation is a large and widespread environmental pressure that is exacerbated by climate change (Eswar *et al.*, 2021; Vellinga *et al.*, 2021). The issue of soil and water salinisation presents a significant challenge to food security as it leads to land degradation, diminishing agricultural productivity, and ultimately contributes to higher rates of agricultural land abandonment (Mukhopadhyay *et al.*, 2021). The situation becomes increasingly challenging for many nations as they grapple with salinity issues alongside severe water scarcity problems, particularly in arid and semi-arid countries (Mekonnen et al., 2016). Global cost estimates by Qadir et al. (2014) indicate that the annual economic losses due to salt-affected land (refers to economic losses based on crop yield losses only) amount to US$27.3 billion. Looking closer on Africa, 80 million ha are estimated to be affected by salinity, up to 68.8 million ha of these are found in the sub-Saharan region (according to Kebede, 2023). Sub-Saharan Africa is lagging behind other regions in terms of water access, management, and supply, contributing to the escalating scarcity of water and the resulting threat to regional security in the area (Freitas, 2015). A promising adaptation strategy is *saline agriculture*, which involves cultivating salt-tolerant crops on salt-affected lands or using brackish water for irrigation. This approach holds the potential to reclaim salt-degraded lands for agricultural production. However, an adequate overview of the extent of salinity in the region is a prerequisite for the effective implementation of this strategy.

Therefore, in this report, we address the following research questions:

1. What is the state of art of scientific knowledge on the problem of salinisation of groundwater and soils in sub-Saharan countries?
2. Which regions are most affected and what are current and future impacts of salinisation in affected regions?

3. How do ICIs address the challenges associated with salinisation and how is the governance landscape of salinity structured in this region?

Addressing the imperative of ensuring global food security amid climate change involves planned adaptation, but barriers reported by practitioners, policymakers, and scientists are impeding the implementation of necessary measures, leading to a widening "adaptation deficit" as the pace lags behind increasing demand (IPCC, 2007; Gagnon-Lebrun & Agrawala, 2007; Tompkins, 2010; Fankhauser & McDermott, 2014). Adaptation governance can be advanced by gaining insights on why institutions emerge and how they enable or constrain adaptation (Bisaro & Hinkel, 2016). This is not an easy undertaking, as the institutional composition of the global environmental governance landscape related to salinisation is increasingly complex (Negacz *et al*., 2021). This aligns with the Western political shift from government to governance that started in the 1970s (Mayntz, 2017). At present, these institutional compositions are characterised by a lack of coordination (Vellinga *et al*., 2021). Considering the contemporary challenges, a sustainable transition in the environmental governance landscape can contribute to adapting food systems to salinisation and thus meet the growing food demand. A sustainable transition can be set in motion by a collective effort of experimental niche initiatives (Rotmans *et al*., 2016).

In the past 10 years, a myriad of international cooperative initiatives (ICIs) has emerged around the topic of salinisation and saline agriculture. These initiatives involve non-state and subnational actors, (such as regions, companies, non-governmental organisations, communities, indigenous peoples, research institutions) often working in collaboration with national governments and intergovernmental organisations. ICIs operate across national borders and perform governance functions related to implementation of salinity-related projects as well as provision of information and funds to achieve common goals (Widerberg *et al*., 2016). As such, they provide an opportunity to address the global challenge of soil and water salinisation.

These ICIs have been mapped for Europe, North Africa and the Middle-East (Negacz *et al*., 2022), and Central and South-East Asia (Smaoui *et al*., forthcoming). Until now, however, little is known about the institutional landscape of saline agriculture ICIs in sub-Saharan Africa.

As salinisation is a multifaceted problem with serious impacts at individual, national and regional levels, affecting farmers' livelihoods and food security, but also damaging agricultural production and thus limiting economic development and prosperity, it is necessary to find solutions that consider this multifaceted nature. The structure of the report attempts to take this into account by considering and analysing different levels. After providing necessary background information on salinity in Chapter 2, Chapter 3 of the report outlines the methodology used, succeeded by Chapter 4 which provides an overview of the current scientific understanding of salinisation at the national level, structured into country profiles for each of the focus countries. Next to key facts and relevant literature on salinity issues in each country, these profiles also include information on current regulations in place. Chapter 5 describes region-wide impacts of salinisation as well as adaptation strategies already in place. Chapter 6 finally presents a comprehensive analysis of the international governance landscape with respect to ICIs. The report concludes with recommendations.

2 Key insights on salinity

Soil and water salinisation are often interlinked and can occur naturally (primary salinisation) through processes such as seawater intrusion, flooding, or unfavourable geological features (Singh, 2021). But salinisation is also often the result of human activities (secondary salinisation). Even though soil salinity can be caused by inherent soil characteristics such as low salt solubility and removal, or by arid climates and low rainfall where excess salts are not washed out of the soil (Cherlinka, 2021), it is mainly caused by unsustainable irrigation practices. These practices include excessive use of fertilisers, irrigation with brackish water, and the lack of adequate drainage systems to remove excess irrigation water. As a result, these practices have led to irreversible contamination of groundwater in many regions through saline water leaching through the soil in groundwater storages (Mohanavelu *et al*., 2021).

However, agricultural practices affect groundwater salinity differently in irrigated and non-irrigated areas. Agricultural activities in areas that are not irrigated can increase groundwater recharge, and sometimes result in salt leaching from the unsaturated zone (Suarez, 1989). Conversely, in irrigated areas, salinisation can result from irrigation with brackish water, saltwater intrusion due to groundwater pumping, downward migration of salt in the unsaturated zone, or dissolution of saline minerals. In addition, salinity can accumulate in groundwater due to the concentration of salts resulting from plant water uptake (Suarez, 1989).

2.1.1 Saline vs. sodic soils

Salt-affected soils include both saline and sodic soils. Saline soils are characterised by high levels of soluble salts in soil water, which adversely affect plant growth by limiting the ability of roots to absorb water, even in wet conditions. The excess salts create an osmotic imbalance, making it difficult for plants to extract water from the soil, resulting in drought-like symptoms and reduced crop yields (NDSU Extension Service, n.d.). On the other hand, sodic soils contain excess sodium ($Na+$) at the exchange sites of the clay particles, leading to deterioration of the soil structure and closure of soil pores. This prevents root penetration and water infiltration, further inhibiting plant growth (NDSU Extension Service, n.d.). Both saline and sodic soils pose significant challenges to agriculture, damaging plants and reducing overall crop productivity.

2.1.2 Salinity measurement techniques

A key measurement method for assessing salinity in both soil and groundwater is electrical conductivity (EC). In the context of soil, on-site measurements are commonly made using portable EC instruments or probes. These devices are inserted into the soil and the resulting readings provide a direct indication of the soil's ability to conduct an electric current, which correlates with its salinity. Measurements are usually expressed in Siemens per metre (S/m), deciSiemens per metre (ds/m), milliSiemens per centimetre (mS/cm), or microSiemens per centimetre (µS/cm). In this report we use the unit ds/m. In the case of groundwater, similar EC measurements are used to determine the salinity of the water (see Table 2). This involves assessing the electrical conductivity of the water, with higher values indicating increased salinity due to the presence of dissolved ions.

Monitoring EC in both soil and groundwater is essential for effective agricultural and water resource management, as it helps to identify salinity-related problems and implement appropriate mitigation strategies (Chan, 2018). The categorisation used for soil salinity assessment can be found in Table 1.

Table 1 Categorisation of soil salinity levels (Shirokova et al., 2000)

Salinity level	**Degree of crops sensitivity**	**Electro-conductivity of soil saturated extract ECe at t=25°C (dS/m)**
Non saline	Very sensitive crops	0-2
Low salinity	Sensitive crops	2-4
Mild salinity	Mildly sensitive crops	4-8
High salinity	Mildly resistant crops	8-16
Severe salinity	Resistant crops	> 16

Table 2 Classification of saline water based on salinity hazard (Rhoades et al., 1992)

Salinity level	**Type of water**	**EC w (dS/m)**
Non-saline	Drinking and irrigation water	< 0.7
Slightly saline	Irrigation water	0.7-2
Moderately saline	Primary drainage water and groundwater	2-10
High saline	Secondary drainage water and ground water	10-25
Very high saline	Very high saline water	25-45
Brine	Seawater	> 45

2.1.3 Salinity mapping techniques

The traditional method of assessing soil salinity involved collecting soil samples in the field and then analysing them in the laboratory to determine solute concentrations or electrical conductivity. This conventional method is not only time consuming but also costly (Allbed & Kumar, 2013). Remote sensing is emerging as a promising and efficient alternative, providing rapid tools for monitoring and mapping soil salinity (Ghabour & Daels, n.d., as cited in Allbed & Kumar, 2013).

Remote sensing involves the analysis of electromagnetic energy reflected from surfaces to obtain information about the earth's features. This method has been used extensively to study the spectral reflectance of saline features on the soil surface as a direct indicator for soil salinity detection and mapping. Challenges arise when factors such as high soil moisture or invisible crustal salt affect the accuracy of this direct approach. In such cases, scattered vegetation or halophytes on the soil surface can indirectly signal salinity problems. This indirect method allows the detection and mapping of areas affected by soil salinity by analysing vegetation reflectance. Unhealthy vegetation has lower photosynthetic activity, resulting in increased visible reflectance and reduced near-infrared reflectance (NIR) (Weiss *et al*., 2001, as cited in Allbed & Kumar, 2013). To create comprehensive soil salinity maps, GIS mapping and spatial analysis is a useful technique to integrate data from different sources, such as soil sampling or remote sensing (Gad *et al*., 2021).

Mapping techniques for groundwater salinity include borehole logging, where direct measurements of electrical conductivity in boreholes can provide information on salinity levels at different depths (Wonik & Olea, 2007). Additionally, remote sensing and GIS mapping are also commonly used techniques to map groundwater salinity (Elmahdy & Mohamed, 2013; Tweed *et al*., 2006).

3 Research design

This section outlines the research process employed to answer the research questions (see Figure 1). Our data collection involved a combination of different methodologies, including an extensive literature review, semi-structured interviews and a systematic content analysis of reports and policy documents available online. Analysis of the collected data was carried out using the qualitative data analysis tool Atlas.ti and descriptive statistics.

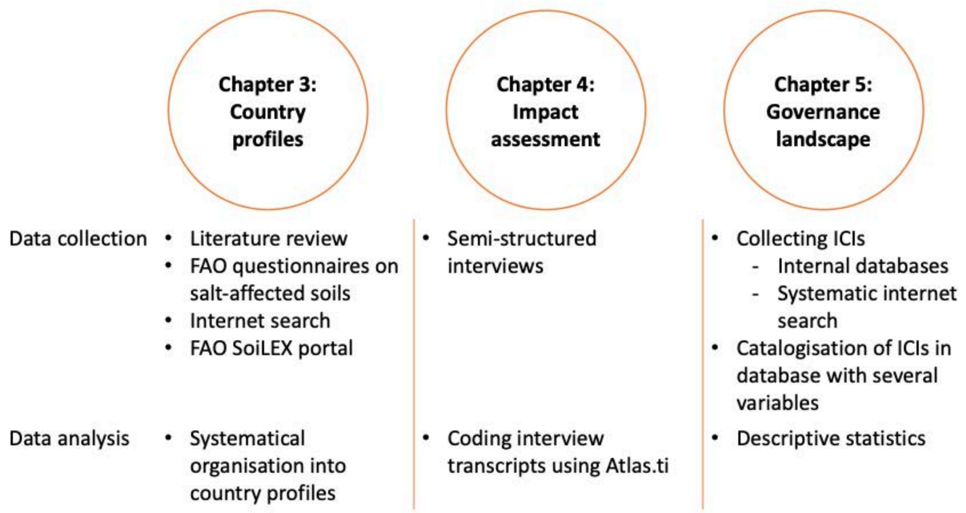

Figure 1 Research process

3.1 Data collection and analysis

To evaluate the current scientific understanding of salinisation in our 12 focus countries, selected based on RVO priorities, we conducted a comprehensive literature review. This was complemented by an examination of FAO questionnaires on salt-affected soils (FAO, 2024), wherever such questionnaire was available for each respective country. The collected information was systematically categorised into country profiles, offering a comprehensive overview of the research landscape for each respective nation. These profiles include a synthesis of key facts, visual representations such as maps and figures on salinisation, and links to relevant literature for further exploration. Within the country profiles, a dedicated section explores the policy landscape of salinity management for each country. This analysis involved cross-referencing information from three different sources: the FAO SoiLEX portal (SoiLEX, 2023), FAO questionnaires on salt-affected soils (FAO, 2024), and an extensive internet search targeting policies in the areas of soil, water, biodiversity, and land degradation addressing salinity and salinisation. This triangulation of data allowed for an integrated and nuanced overview of current policies, providing a solid basis for subsequent analysis and recommendations.

In order to assess both the current and future impacts of salinisation in sub-Saharan Africa, we conducted semi-structured interviews with extension officers and experts. To facilitate these discussions, we developed a comprehensive interview guide consisting of 15 questions. We extended invitations to potential participants through email correspondence, employing a snowball approach to maximize outreach and engage as many participants as feasible. The transcripts of these interviews were then thoroughly coded using the data analysis tool Atlas.ti, resulting in the identification of 22 different codes derived from the various interview questions (Appendix B.1). In addition, where appropriate, the findings from the interviews were incorporated into other chapters, such as the chapter on available scientific knowledge or the chapter on policy recommendations.

To analyse the governance landscape of salinisation in the selected countries, we used the methodology developed by Negacz *et al*. (2022). We focus on international and cooperative initiatives (ICIs). Such initiatives involve collaboration 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 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 adopted a dual approach: First, salinisation-related initiatives were collected through an examination of various databases. Second, a systematic internet search using a predefined set of keywords (Appendix A.1) was conducted, applying a snowballing approach. The collected initiatives were then catalogued in a database. Next, various variables (e.g. types of actors, governance functions, thematic focus, funding schemes) were collected. The database was validated through both an automated keyword analysis and an expert review to ensure data relevance (Appendix A.2). The variables were subsequently analysed using descriptive statistics and a governance triangle showing government, corporate or civil society actors, developed by Abbott and Snidal (2009a; 2009b, see Figure 2).

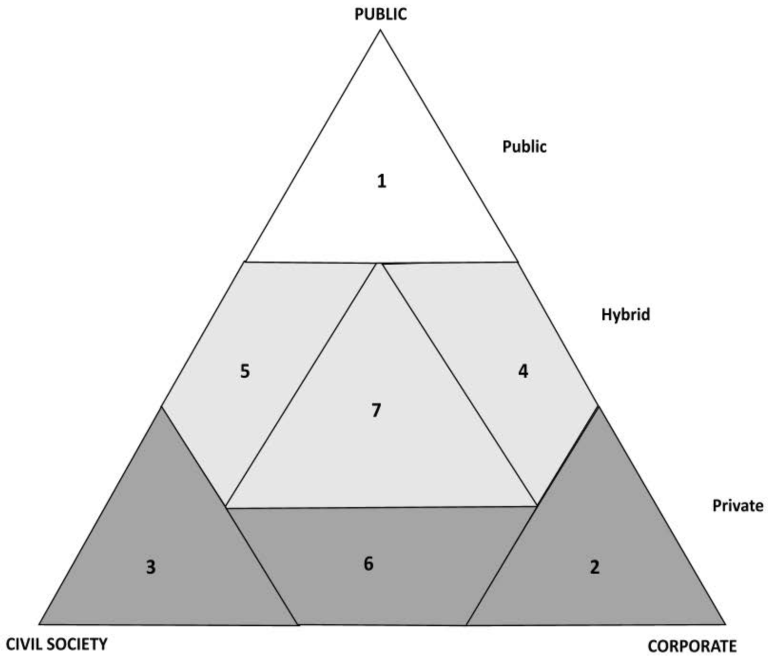

Figure 2 *The governance triangle. The seven zones indicate the composition of actors: (1) public, (2) corporate, (3) civil society, (4) public-private, (5) civil society-public, (6) private-civil society, (7) public-corporate-civil society (Abbott and Snidal, 2009a; 2009b).*

3.2 Limitations

Despite a rigorous research process, this study is subject to some limitations while interpreting our findings. First, our approach to ICIs may not capture all active initiatives due to potential gaps in keywords and the reliance on English and French for search terms, potentially excluding initiatives documented in national languages or because some ICIs are not represented online. This methodological focus may introduce bias into our sample of ICIs and limit the scope of our database. Furthermore, the small size of our analysed sample calls for caution in generalising our findings, especially when making comparisons with other governance areas. Finally, challenges of connectivity, geographical separation and time differences made it difficult to reach representatives from all selected countries. The findings from the interviews may not fully represent the diversity of perspectives, challenges, and local solutions in all 12 focus countries, but offer a snapshot of the overall salinisation scenario in the wider region. Despite these limitations, our study provides valuable Insights into the governance landscape of salinisation within the given constraints.

4 State of the art of scientific knowledge on salinisation of soils and groundwater: Local level

4.1 Overview

In sub-Saharan Africa, soil, and groundwater salinisation are often addressed in the context of soil degradation analysis (Tully *et al*., 2015), or analysis on groundwater availability and quality (Pavelic *et al*., 2012). There are only a few publications focusing exclusively on a region-wide analysis of either soil or groundwater salinity. It is notable that estimations regarding the extent of soils affected by salinity vary widely among sources for this region. However, a chapter by Kebede in the published book "Biosaline Agriculture as a Climate Change Adaptation for Food Security" (2023) assesses the status, drivers, and potential management options for saline soils in Africa, also covering the sub-Saharan region. The scarcity of evidence regarding the scale of African groundwater salinisation within global research, is addressed by Gurmessa *et al*. (2022). Another study concentrates on groundwater salinity in the Horn of Africa which covers our focus countries Ethiopia, Kenya, and Somalia (Araya, Podgorski & Berg, 2023). Below, we present an overview of the soil and groundwater salinity in the region based on the recently published studies.

4.1.1 Soil salinity

Key facts:

- The extent and rate of soil degradation in sub-Saharan Africa remains uncertain due to a lack of reliable data and only rough estimates (Tully *et al*., 2015).
- The assessment of soil salinisation in sub-Saharan Africa varies widely, ranging from 19 million ha (Tully *et al*., 2015) to 68 million ha (Kebede, 2023). This variability highlights the imprecision in measurements and the limited availability of data on the subject.
- Salt-affected soils pose challenges to agricultural productivity, ecological stability, and economic well-being, leading to potential social unrest and causing climate migration (Kebede, 2023; Pandey *et al*. 2023).
- Environmental degradation, which included salinisation, results in a loss of 4-12% of Africa's GDP (ADR, 2012, as cited in Kebede, 2023). In sub-Saharan Africa, approximately 180 million people are affected (Mirzabaev *et al*., 2014, as cited in Kebede, 2023), and the economic cost of land degradation is estimated at €62 billion annually (Nkonya *et al*., 2016, as cited in Kebede, 2023).
- The expansion of irrigated agriculture is likely to exacerbate salinity problems. According to research by Dewitte *et al*. (2013, as cited in Kebede, 2023), approximately 200 million ha of land in Africa could face potential salinity problems if semi-arid soil regions are irrigated.
- Kebede (2023) identifies a number of African countries in our scope where salt-affected soils are prevalent: Chad, Ethiopia, Kenya, Mali, Mozambique, Niger, Senegal, Somalia, and Sudan.
- According to Kebede (2023), in Africa, like in other parts of the world, salt-affected soils are primarily the result of factors such as seawater intrusion, mineral/rock

weathering, groundwater-related salinity, irrigation-related salinity and climate-change-related salinity.

Relevant literature

- *The State of Soil Degradation in sub-Saharan Africa Baselines, Trajectories, and Solutions* (Tully *et al*., 2015)
- Chapter 13: Status, Drivers, and Suggested Management Scenarios of Salt-Affected Soils in Africa (Kebede, 2023) in *Biosaline Agriculture as a Climate Change Adaptation for Food Security*

4.1.2 Groundwater salinity

Key facts

- Gurmessa *et al*. (2022) highlight that out of 12,225 data points, 80% of the water schemes they examined in Africa have no to low salinity (<2 dS/m = <2000 µS/cm, as in Figure 3) and are suitable for irrigation and drinking.
- Samples with conductivity values above 2 dS/m (> 2000 µS/cm, as in Figure 3) are restricted to specific geological and climatic conditions. The results indicate that, in general, salinity does not affect the water security status of most African countries. However, in arid regions (i.e. Ethiopia), characterised by low groundwater recharge, salinity affects water quality (Gurmessa *et al*., 2022).

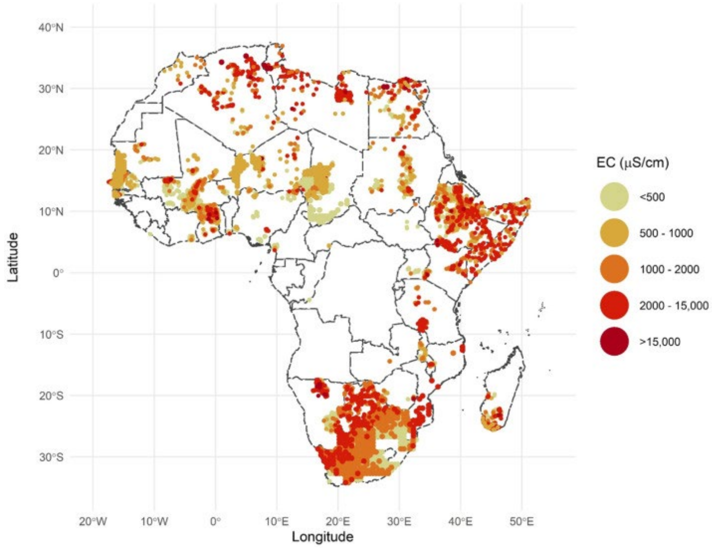

Figure 3 Distribution of EC in groundwater across Africa (Gurmessa et al. 2022, p.4)

- In the Horn of Africa, an uneven distribution of groundwater salinity affects primarily eastern regions, including Kenya's Chalbi and Nyiri deserts, Ethiopia's Ogaden desert, Djibouti, and most of Somalia (see Figure 4). According to Araya *et al*. (2023) Approximately 11.6 million people, or 7% of the population, are exposed to salinity, with Somalia experiencing the most significant impact, affecting around 5 million people, or half of its population.

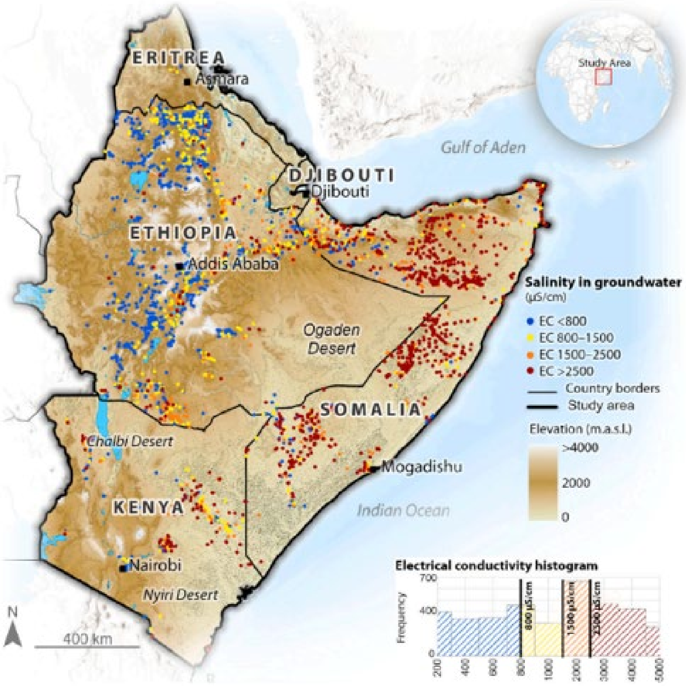

Figure 4 Concentration ranges of measured salinity in groundwater (Araya et al. 2023, p. 3)

Relevant literature

- *Assessing groundwater salinity across Africa* by Gurmessa *et al*. (2022)
- *Groundwater salinity in the Horn of Africa: Spatial prediction modeling and estimated people at risk* by Araya, Podgorsko & Berg (2023)
- *Groundwater availability and use in sub-Saharan Africa: A review of 15 countries* by Pavelic *et al*. (2012)

As the region-wide literature review provides little information on the extent of salinity in individual countries, the following 12 country profiles provide more detailed insights on the state of scientific knowledge on salinity of soil and groundwater resources at the country level. In addition to summarising key facts from the reviewed publications, these country profiles also provide policy insights on salinity.

4.2 Country profiles

In this section, we present the key facts and figures about salinity in each of the sub-Saharan countries.

4.2.1 Burkina Faso

Burkina Faso is a landlocked West African country with a dry tropical climate, experiencing a short rainy season and long dry season (UNDP, 2021). Most of Burkina Faso's soils are not affected by salinity, based on the existing body of literature (see Table 2, Kabore *et al*., 2021). However, Barry & Obuobie (2012) infer from different sources that groundwater salinity is a widespread problem. Scientific knowledge on groundwater quality and soil salinity in Burkina Faso is fairly well developed.

Key facts

- Most soils in Burkina Faso have very low salinity. Additionally, Burkina Faso's soils are mostly acidic, with more than 90% of soils having pH between 4.5 and 6. Nearly 95% of soils have no salinity, while only about 4% of the area shows a slight salinity (see Table 3; Kabore *et al*., 2021).
- The spatial distribution shown in Figure 5 illustrates groundwater salinities >1 dS/m in Burkina Faso, indicating the widespread prevalence of salinity problems (Barry & Obuobie, 2012).

Table 3 Level of salinity of soils in Burkina Faso (adapted from Kabore et al. 2021)

Level	Percentage	
	0 - 30 cm	30 - 100 cm
Moderate Salinity	0.006	0.001
None	95.1278	94.617
Slight Salinity	4.708	5.357
Slight Sodicity	0.008	0.007
Total	100	

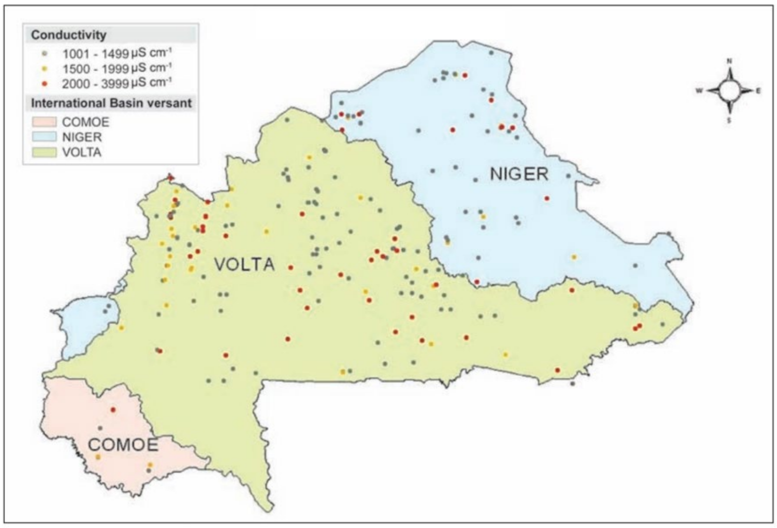

Figure 5 Distribution of conductivity > 1000 µS cm-1 in Burkina Faso (MAHR, 2003, as cited in Barry & Obuobie, 2012.)

Policy insights

Burkina Faso addresses salinity regulation in its National Water Policy, overseen by the Ministry of Agriculture, Water Resources, Sanitation, and Food Security. The policy emphasises international cooperation and capacity building, and specifically mentions desalination as a technique to ensure access to water supply and sanitation services as part of a commitment to sustainable water management by 2030.

Relevant literature

- Statement of soil salinity in Burkina Faso by Kabore *et al*. (2021)
- Chapter 2: Burkina Faso by Barry & Obuobie in Groundwater availability and use in sub-Saharan Africa: A review of 15 countries by Pavelic *et al*. (2012)

4.2.2 Chad

Chad is a landlocked country in central Africa, with a climate ranging from very hot and arid to semi-arid to subtropical. It is one of the hottest and driest countries in the world and has been experiencing prolonged drought for decades (UNDP, 2023). Limited scientific resources regarding groundwater and soil salinity indicate medium salinity levels.

Key facts

- In the Kanem region, the groundwater conductivity reaches a maximum value of 0.1 dS/m and can therefore be classified as non-saline (see Table 2).
- In the Bahr el Ghazal region salinity values are slightly higher and vary from 0.01 dS/m to 0.14 dS/m. However, they can still be categorised as non-saline (see Table 2). This indicates that most groundwater in this region is suitable for irrigation on all types of soils with moderate leaching (see Figure 6, Wilczok *et al*., 2014).
- As there is not enough literature on the subject, this information cannot be taken as complete. Especially as there are also sources that predict a high level of soil salinity in Chad (Kebede, 2023).

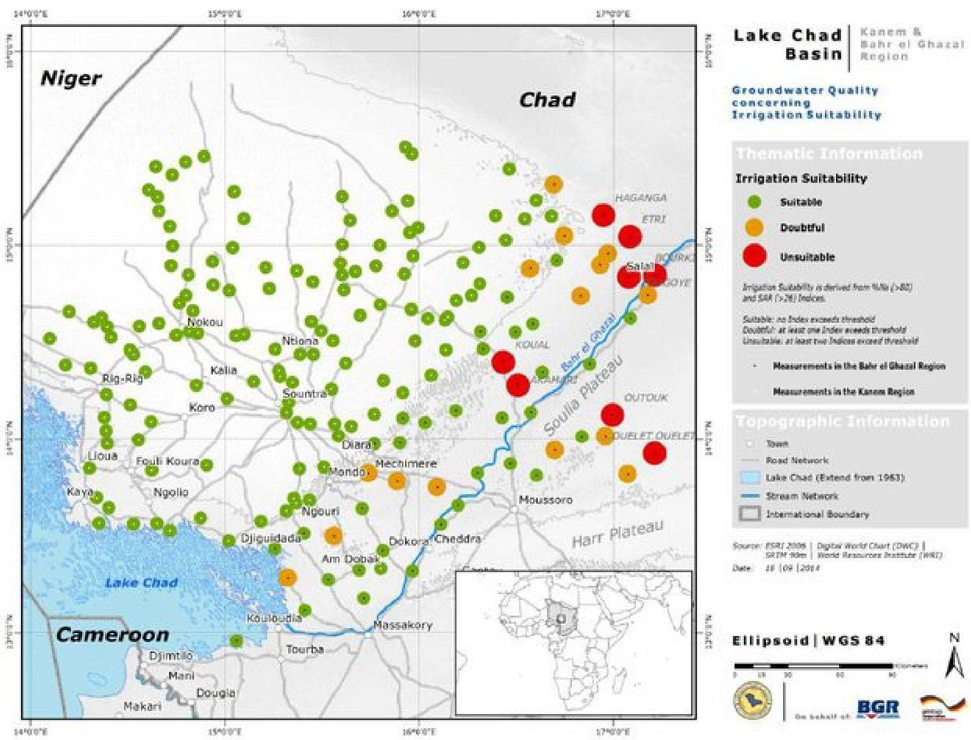

Figure 6 Groundwater classification regarding irrigation suitability (Wilczok et al., 2014)

Policy insights

Our research on the regulation of salinisation in Chad revealed a lack of national policies directly addressing it. However, salinity is acknowledged under international agreements such as the First National Adaptation Plan to Climate Change and the Report on Land Degradation Neutrality under the United Nations Convention to Combat Desertification (UNCCD), highlighting its threat to biodiversity and land degradation. Notably, the 4th National Report on Biodiversity under the Convention on Biological Diversity (CBD), proposes concrete solutions to salinisation, including mitigating the impact of artisanal salt and natron extraction in the Ngouri and Baga Sola departments, as well as developing clear rules for the protection of intellectual property rights.

Relevant literature

- Groundwater Quality Investigations in the Kanem and Bahr el Ghazal regions, Chad by Wilczok, Vasollo, and Seeber (2014)

4.2.3 Ethiopia

Ethiopia is located in north-eastern Africa and has a diverse climatic landscape. Among our focus regions, Ethiopia stands out as a country where a considerable volume of research on salinity has been published to date, especially in comparison to other nations in sub-Saharan Africa. This may be because according to some sources, Ethiopia is the country most affected by salt-affected soils in Africa (Sileshi, 2016, cited in Tessema *et al*., 2023). Ethiopia is a landlocked country. Salinisation here is a serious problem mainly in irrigated arid and semi-arid areas (Borena & Hassen, 2022).

Key facts

- In Africa, Ethiopia is the country with the highest extent of salt-affected soils. It ranks seventh in the world in terms of the proportion of land affected by salinity (Sileshi, 2016, as cited in Tessema *et al*., 2023).
- According to a recent report, around 44 million ha (36% of the country's total land area) are at potential risk of salinity issues, including 33 million ha with dominant salinity, 8 million ha with combined salinity and alkalinity, and 3 million ha with dominant alkalinity (Seid, M. & Genanew, T., 2013).
- According to Tesfaye *et al*. (2014, as cited in Borena & Hassen, 2022), salt impacts around 4.9 million ha of land in the eastern and southern dry and semi-arid regions, with notable salt and alkalinity concerns in the semi-arid and arid lowlands and mid-Awash valleys (Seid, M. & Genanew, T., 2013). This is mainly due to inadequate rainfall (less than 400 mm) and high evapotranspiration (Birhane, 2017, as cited in Borena & Hassen, 2022).
- Regions strongly affected by salinity are areas between Ziway and Shala, around the Abaya and Chamo lakes, the Rift Valley, and the basins of the Awash and Omo rivers. Saline soils also exist in the Wabe Shebelle River Basin, the Denakil Plains and numerous other lowlands and valleys throughout the country, where approximately 9% of the population live (Sileshi & Kibebew, 2016; Bayleyegn *et al*., 2018, as cited in Borena & Hassen, 2022). The main concentration of saline soils is in the lowlands of

Expert insights

Salinity hotspots:

- Rift Valley, from the North East of the country to the South East
- Lower basin of the Wabe Shebelle and Omo rivers
- Somali and lowlands of Oromia
- Amhara and Tigray regions

Promising crops for adaptation:

- Sorghum
- Maize
- Cereals
- Cotton

Afar, Somalia, and parts of Oromia, Amhara, Tigray, and the southern regional states (see Figure 7a-d, Quershi *et al.,* 2019b).

- Not all salt-affected areas are mapped and there is no official protocol for mapping soil salinity (FAO, 2024).
- Ethiopian farmers rely on indicators such as white crust and dark brown soil to identify salinity. Salinity problems are often associated with poor irrigation and dysfunctional drainage systems (Qureshi *et al*., 2019a). Practices to manage salt-affected soils include reducing evaporation, improving soil structure, improving infiltration, chemical amendments, and crop adaptation (FAO, 2024).
- Salinity has direct and indirect impacts on household livelihoods, including land abandonment, reduced crop production, declining farm incomes, food insecurity, and increased dependence on food aid. In salt-affected areas, farmers experience production losses of 10-70% due to soil salinity and lack of agricultural inputs (Qureshi *et al*., 2019a).

Policy insights

In comparison to the other focus countries discussed, Ethiopia employs a comprehensive approach to regulate salinisation through various policies. The Afar National Regional State Rural Land Use and Administration Policy (2008) addresses salinisation in the context of land degradation, while the Benishagul Gumz Regional State Rural Land Administration and Use Proclamation No. 85/2010 focuses on threats of salinity to water use and irrigation. The Ethiopian Environmental Policy (1997) emphasises incorporating the potential costs of soil-degradation, including salinisation, in economic analyses for agricultural development. The Land Degradation Neutrality Report under the UNCCD sets a target for improved productivity of more than 14 million ha of cropland by 2031 by mitigating arable land deterioration, including salinisation. Additionally, the Environmental Aspects of the Irrigation Development Strategy outlined in the Ethiopian Water Sector Strategy (2001), highlights the exploration of technological options to mitigate various concerns, including salinisation.

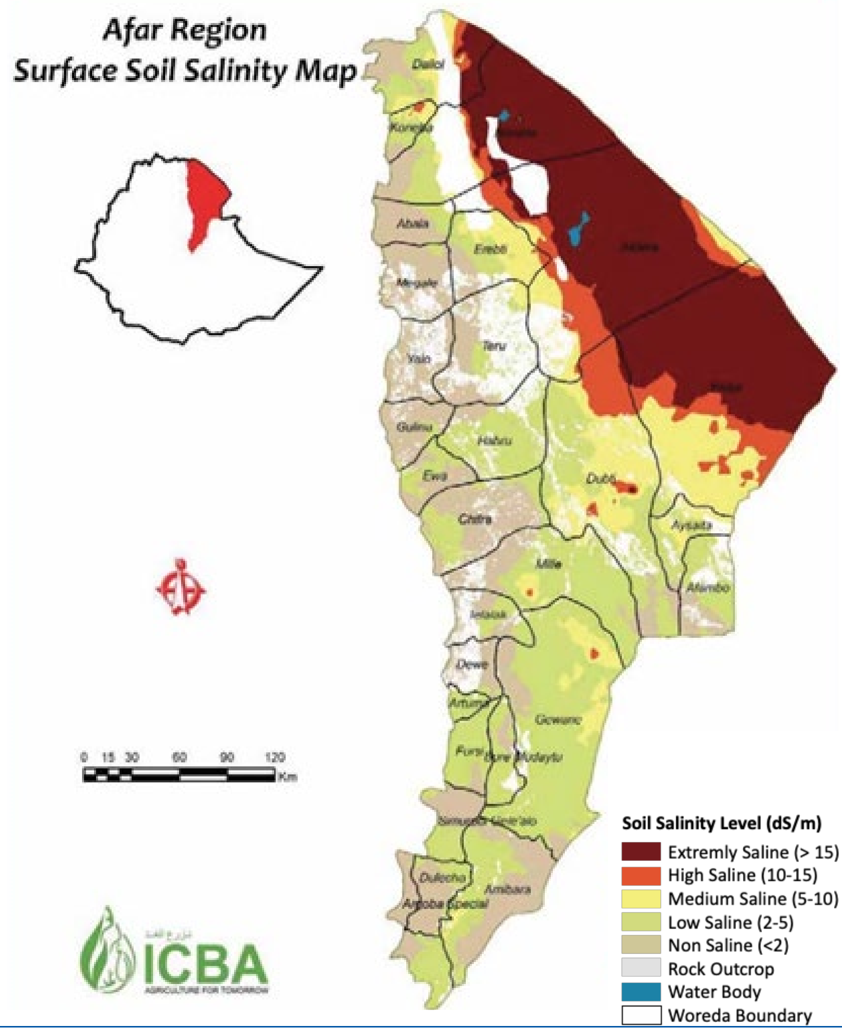

Figure 7a *Surface soil salinity (0–30 cm) maps of Afar regions of Ethiopia (Qureshi et al., 2019b)*

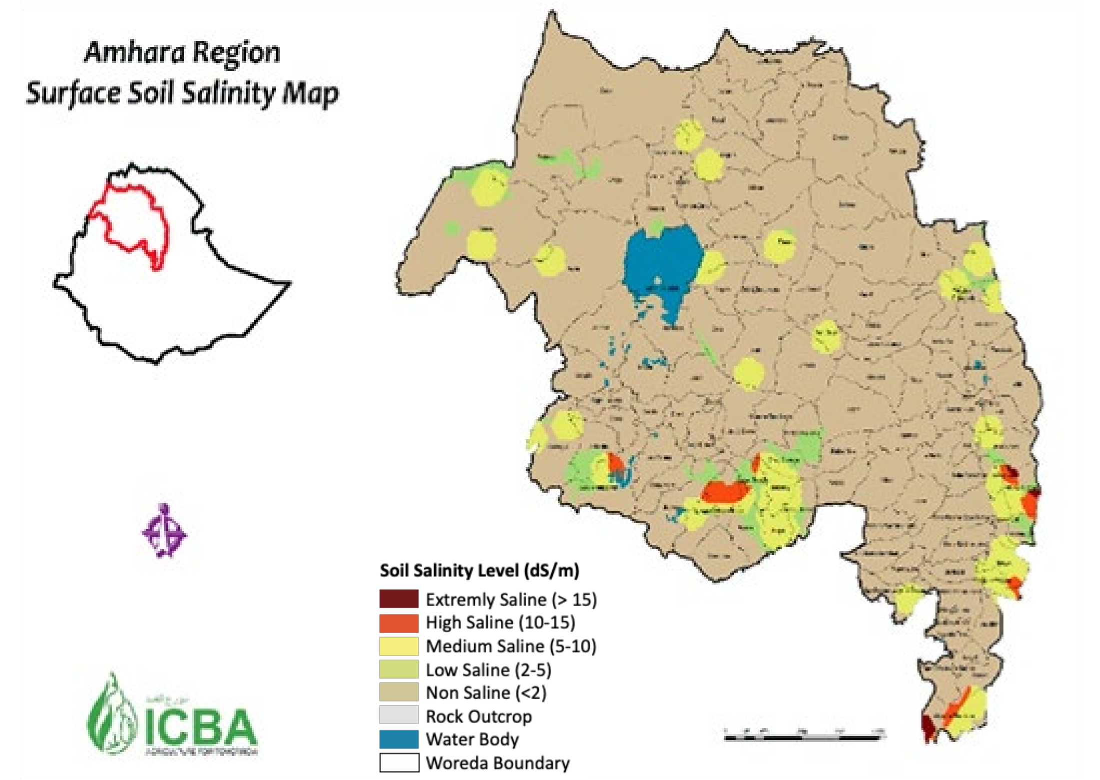

Figure 7b *Surface soil salinity (0–30 cm) maps of Amhara region of Ethiopia (Qureshi et al., 2019b)*

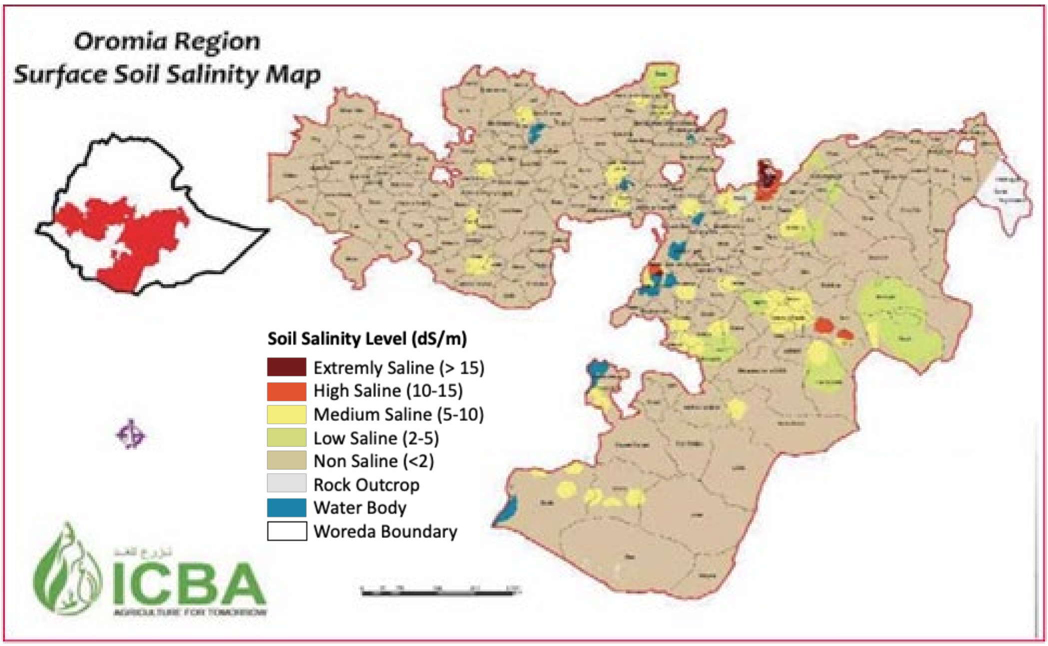

Figure 7c *Surface soil salinity (0–30 cm) maps of Oromia region of Ethiopia (Qureshi et al., 2019b)*

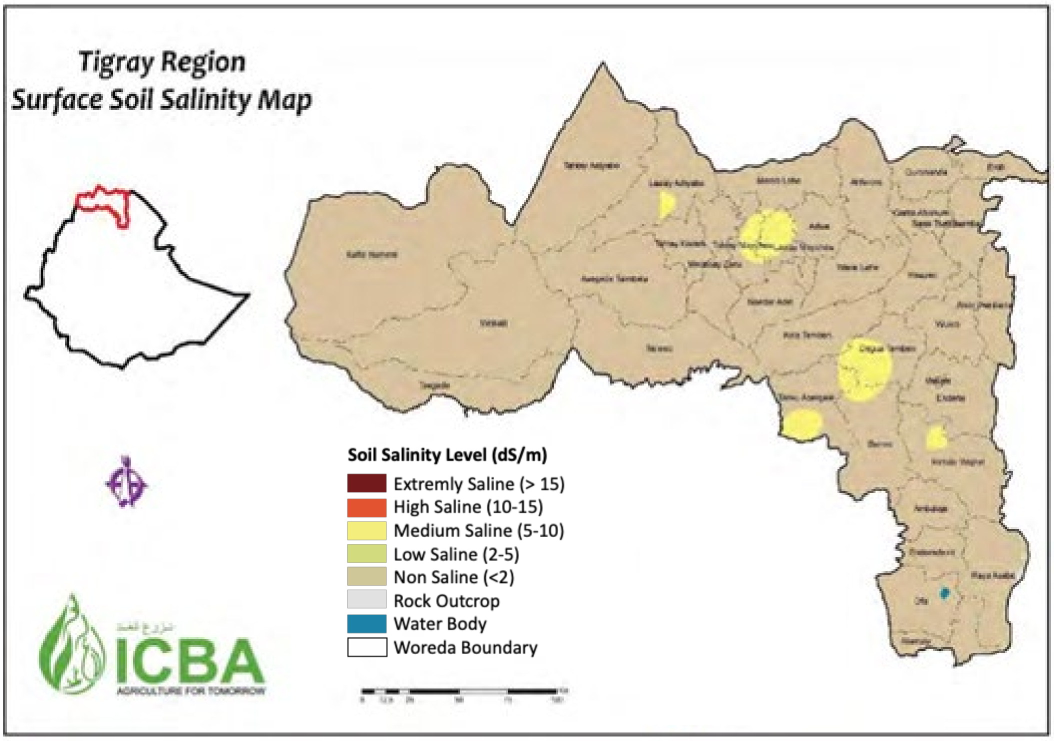

Figure 7d Surface soil salinity (0–30 cm) maps of Tigray region of Ethiopia (Qureshi et al., 2019b)

Relevant literature

- Soil and Irrigation Water Salinity, and Its Consequences for Agriculture in Ethiopia: A Systematic Review by Tessema *et al*. (2023)
- Impacts of Soil Salinity on Irrigation Potential: In the Case of Middle Awash, Ethiopian Review by Borena & Hassen (2022)
- Review of Soil Salinity and Sodicity Challenges to Crop Production in the Lowland Irrigated Areas of Ethiopia and Its Management Strategies by Daba & Qureshi (2021)
- Improving agricultural productivity on salt-affected soils in Ethiopia: Farmers' perceptions and proposals by Qureshi *et al*. (2019a)
- Extent, characterization and management strategies for salt-affected soils in Ethiopia by Quershi *et al*. (2019b)
- Evaluation of soil and water salinity for irrigation in North-eastern Ethiopia: Case study of Fursa small scale irrigation system in Awash River Basin by Seid & Genanew (2013)
- Effect of Salinity on Yield and Yield Related traits of some Accessions of Ethiopian Lentil (Lens culinaris M.) under Greenhouse Conditions by Tesfaye, Petros & Zeleke (2014)

4.2.4 Kenya

Kenya, a coastal country in East Africa, is highly vulnerable to regular climate shocks, leading to significant economic risks. Unless adaptation measures are taken, climate change could not only disproportionately impact the poor, but it could also lead to a loss of up to 7% of real GDP by 2050 compared to baseline (World Bank Group, 2023). Kenya faces salinity in several regions inland and on the coast. Among our focus countries, it is one of the better studied, with some analyses of soil and groundwater salinity available. Overall, it is interesting to observe that most of the publications on Kenya come from authors at local universities and institutions. This suggests that the topic of salinity is of relevance within a regional, country-specific context.

Key facts

- Saline soils in the southern Rift Valley are located near the soda lakes and have high levels of sodium, chlorides, carbonates, and bicarbonates, making them unique in Kenya (Mugai, 2004). Other saline units were found in northern and eastern Kenya and were generally more saline than these in the southern Rift Valley (Mugai, 2004).

Figure 8 Saline soils and salinity type zones of Kenya (Mugai, 2004)

- The Turkana area had arid conditions and salinity mainly due to mineral weathering, while the coastal area had salinity due to *in situ* salt accumulation and lacustrine influence (Mugai, 2004). In Turkana's Turkwel Scheme, the assessment of the impact of irrigation on soil and water quality shows that non-irrigated fields with shallow-rooted pastures for livestock have low surface salinity. However, salt concentrations peak at 0.20m depth (EC 5.57 ds/m; mild salinity) due to salt deposition from evaporation, declining to a non-saline level (EC 1.85 ds/m) at 0.60m depth (Ndegwa & Kiiru, 2010).
- Intensively irrigated fields had low salinity that supported vegetable production, with salt leached by frequent irrigation (Ndegwa & Kiiru, 2010). Periodically irrigated fields showed a strongly saline soil surface due to salt translocation from the shallow groundwater table. Over-irrigation and inadequate drainage caused rising groundwater levels, leading to soil salinisation (Ndegwa & Kiiru, 2010).
- Efficient irrigation practices, drainage systems, and water management are crucial for sustainable agriculture production in the Turkana district (Ndegwa & Kiiru, 2010).

Expert insights

Salinity hotspots:
- Turkana region
- Kitui region
- Coastal areas
- River deltas

Promising crops for adaptation:
- Rice
- Swiss chard

Policy insights

Kenya employs policies to regulate salinisation and addresses salt-affected soils under The National Agricultural Soil Management Policy 2020 (NASMP). This is confirmed by consultations with national experts and our own research. The policy includes for example the National Irrigation Policy 2017 (NIP) which recognises soil conditions such as salinity as limitations for expanding irrigated agriculture and emphasises the need for soil assessment before initiating irrigation projects. The NIP recommends holistic agricultural water management, including agronomic practices and soil fertility management. Additionally, The Crops Act (2013) includes provisions for soil fertility maintenance, soil testing, and regulation of soil salinisation. The NASMP explicitly acknowledges that certain regulations, such as The National Land Use Policy and The Draft National Land Reclamation Policy (2013), do not address issues of soil salinity. It underscores the need for fundamental transformations in soil management practices to meet the challenges of global demand for cereals and food security, aligning with global soil management guidelines and targets for poverty reduction and food security.

Relevant literature

- Salinity characterization of the Kenyan saline soils, Soil Science and Plant Nutrition by Mugai (2004)
- Investigations on soil and water quality as affected by irrigation in Turkana district, Kenya by Ndegwa & Kiiru (2010)
- Effect of soil salinity on plant distribution and production at Loburu delta, Lake Bogoria National Reserve, Kenya by Onkware (2001)

4.2.5 Mali

Mali is highly vulnerable to climate change, including rising temperatures and extreme weather events, leading to increased food insecurity for nearly a quarter of the population, and urgent action is needed to prevent further economic damage (Tucker, 2023). Mali is mostly affected by secondary salinisation as irrigation has increased groundwater and soil salinity (Barry & Obuobie, 2012). However, due to a lack of scientific knowledge and data, the extent of salinity and the severity of the land affected is difficult to determine.

Key facts

- According to Valenza *et al*. (2000), salinity issues in the lower Kala area of Mali result from three factors: the presence of ancient saline deposits, recent irrigation raising the water table and leaching old saline deposits, and intense evapotranspiration leading to salt accumulation in the surface soil. A possible solution involves the implementation of effective managed drainage systems to remove mineralised water from alluvial deposits, though such a system is currently absent.
- Another study concludes that in many regions of Mali, groundwater is typically fresh and of good quality, although certain areas have reported issues with salinity and elevated nitrate levels (British Geological Survey, 2002). These salinity problems are mainly associated with modern irrigation practices (Barry & Obuobie, 2012).

Policy insights

Salinisation in Mali is addressed only under policies regulating water, soil, and land degradation. In line with the Agricultural Orientation Law, there is an emphasis on promoting collaborative projects across sectors. The objective is, among others, to prevent water overuse, thereby mitigating the risk of salinisation, and to enhance agricultural productivity without causing soil erosion or salinisation. In the National Plan for integrated Soil Fertility Management in Mali, published by the Ministry of Rural Development, salinisation is frequently addressed in terms of water management and soil degradation.

Relevant literature

- Influence of groundwater on the degradation of irrigated soils in a semi-arid region, the inner delta of the Niger River, Mali by Valenza, Grillot & Dazy (2000)
- Chapter 7: Mali by Barry & Obuobie, 2012 in Groundwater availability and use in sub-Saharan Africa: A review of 15 countries by Pavelic *et al*. (2012)

4.2.6 Mozambique

Mozambique is an East African country with a long coastline on the Indian Ocean. It is severely affected by salinity from seawater intrusion, but also faces salinisation of inland soils, as reported by interviewees and confirmed by scientific research. Compared to other focus countries, scientific research on Mozambique exists, but needs to be expanded given the country's high vulnerability to salinisation.

Key facts

- According to Naafs & Rhebergen (2012), the quality of groundwater in Mozambique's aquifers varies, with most being fresh, especially in the basement complex and volcanic terrains.
- However, certain areas in the south, particularly the Tertiary aquifers, have salinity problems due to natural seawater intrusion and marine sedimentation, resulting in brackish groundwater (Naafs & Rhebergen, 2012).
- In regions such as Gaza, Maputo and Inhambane provinces, groundwater often exceeds WHO drinking standards for electrical conductivity (1.5 dS/m) (Naafs & Rhebergen, 2012).
- Localized groundwater salinisation is occurring in the Chokwe area (Gaza Province) due to extensive irrigation practices that have raised the water table and increased salinity levels, resulting in the loss of approximately 2,000 ha of land for crop production out of 30,000 ha (Naafs & Rhebergen, 2012).
- Salinity issues in Mozambique make large parts of the southern country unsuitable for groundwater-based irrigation (Naafs & Rhebergen, 2012).

Expert insights

Salinity hotspots:
- Coastal areas
- Southern areas of the country
- Gaza region (rice production area)
- Zambezia Province
- Nampula province
- Maputo province

Promising crops for adaptation:
- Sorghum
- Millet
- Barley
- Cowpea

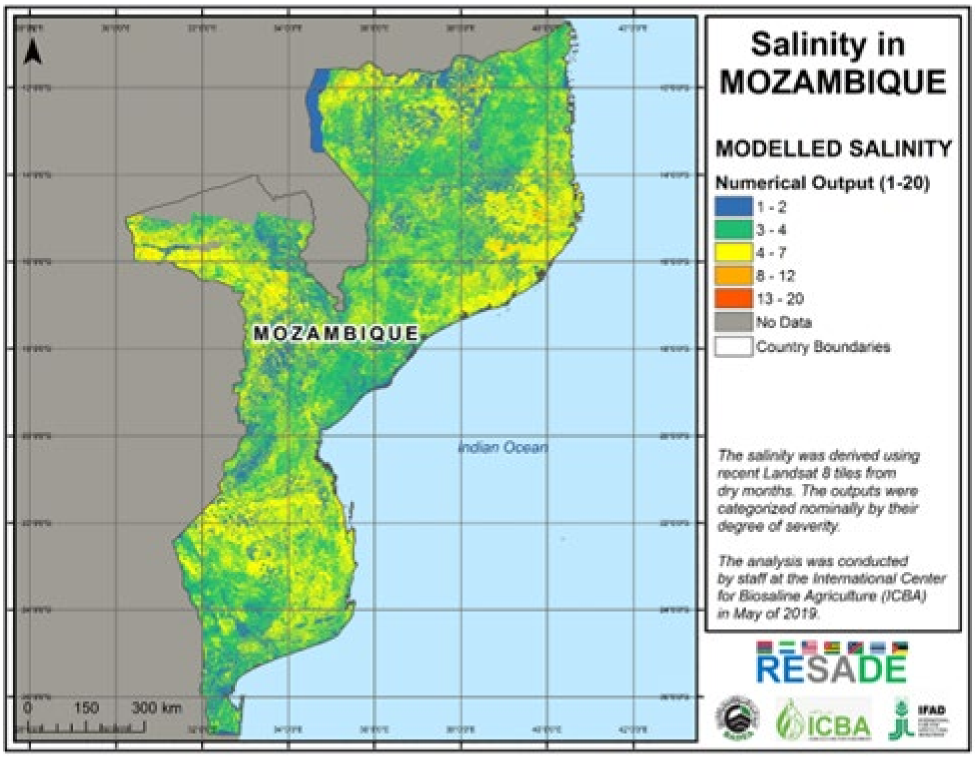

Figure 9 Salinity Map Mozambique, RESADE Project

Policy insights

Mozambique lacks specific policies on regulating soil and groundwater salinisation, as indicated by consultations with salinity experts and cross-referencing online sources. While negative impacts of salinisation on soils are acknowledged in the Programme for Integrated Development and Adaptation to Climate Change in the Zambezi Watercourse under the Environmental and Social Management Framework (ESMF), the framework does not explicitly outline regulatory measures for salinisation. Despite project activities, including desalination efforts, the document does not provide specific regulations for addressing salinisation concerns.

Relevant literature

- Chapter 8: Mozambique by Naafs & Whebergen, 2012 in Groundwater availability and use in sub-Saharan Africa: A review of 15 countries by Pavelic *et al*. (2012)
- Simulating the effects of sea level rise and soil salinization on migration and adaptation in coastal Mozambique by Pandey *et al*. (2023)

4.2.7 Niger

Niger is a landlocked country in West Africa. The country has a warm climate with extremely high temperatures throughout the year. It experiences a long and intense dry season from October to May, and a short and unpredictable rainy season associated with the West African monsoon (World Bank Climate Change Knowledge Portal, n.d. a). There is not a lot of data available on the extend of salinity issues in Niger. However, some studies address salinity in the context of soil fertility and as the source of irrigation water (Kuti *et al*., 2018). Additionally, one study assesses soil salinity in the southern part of Niamey, within the Niger basin (Moussa *et al*., 2020).

Key facts

- In Niger, surface water resources are limited, and the country heavily relies on groundwater for domestic water supply, but there is a scarcity of information on groundwater quality and quantity (Hassane, 2010).
- Over-exploitation of shallow groundwater due to increased use of motorised pumps for irrigation is also a growing issue. However, in a study of groundwater quality in the southwest, it was found that salt content in groundwater in certain areas, such as the Niger river valley and the Continental Terminal, is generally low (Hassane, 2010).
- The chapter on Niger is not very informative in terms of salinity, confirming the general lack of research on it.

Policy insights

Regulation of salinisation in Niger is addressed within policies for soil, biodiversity, and land degradation. The Strategic Framework for Sustainable Land in Niger and its Investment Plan 2015-2029 (Cadre Stratégique de la Gestion Durable des Terres au Niger et son Plan d'Investissement 2015-2029 or CS-GDT) proposes several measures to address and regulate salinisation by region, ecosystem, and production system. For example, the development of small-scale irrigation, the promotion of environmental education, or the conservation of biodiversity.

Relevant literature

- Assessment of soil salinity and irrigation water quality of Chanchaga Irrigation Scheme I, Minna, Niger State by Kuti *et al*. (2018)
- Soil salinity assessment in irrigated paddy fields of the Niger Valley using a Four-Year Time series of Sentinel-2 satellite images by Moussa *et al*. (2020)
- Aquifers superficiels et profonds et pollution urbaine en afrique: Cas de la communauté urbaine de Niamey (NIGER) by Hassane (2010)
- Chapter 9: Niger by Barry and Obuobie, 2012 in Groundwater availability and use in sub-Saharan Africa: A review of 15 countries by Pavelic *et al*. (2012)

4.2.8 Senegal

Senegal is a Sahelian country in West Africa with two seasons: a rainy season from October to May and a dry season from June to September (World Bank Climate Change Knowledge Portal, n.d. b). Senegal is severely affected by salinity, particularly along its coastline (Thiam *et al*., 2021). There is already relatively extensive research on salinisation in some areas of Senegal, and salinisation is also addressed in the context of the interrelated challenges of climate change affecting economic growth in Senegal (Faye *et al*., 2021).

Key facts

- Land use, soil and crop types influence salt distribution in the Djilor district, with high salt content in fallow land, bare land, rice fields, and fluvisols. There are significant associations between soil EC and clay content, distance to the river, and elevation (Thiam *et al*., 2019).

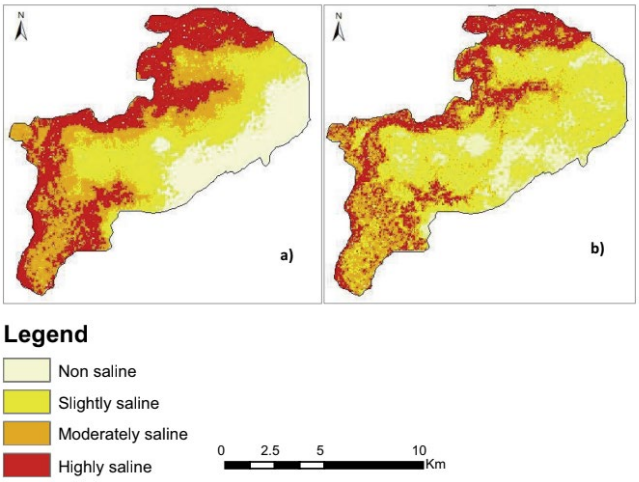

Figure 10 Soil salinity maps from the years 1984 (a) and 2017 (b), Thiam et al. (2021)

- Contrary to previous studies, salinity was not correlated with groundwater depth, indicating that seawater intrusion is the primary cause of low crop yields, especially in rice production, which is mainly managed by female farmers who use various coping strategies, including chemical fertilisers, manure, tree planting, and soil bunds (Thiam *et al*., 2019).
- Despite a slight decrease in soil salinity levels for the years 1984 and 2017, soil salinity continues to contribute significantly to soil degradation in the Djilor region. It covered about 60% of the area in 1984 and 45% in 2017. According to Thiam *et al*. (2021), the spatial distribution is strongly related to the vegetation in the area, where highly saline soils are mainly found in non-vegetated areas, and non-saline areas are located in vegetated regions.
- The extent of land salinisation needs proper assessment, with estimates ranging from 925,000 to 1,7 million ha, including approximately 625,000 ha severely affected (Faye *et al*., 2021).

Policy insights

Policies in Senegal address salinisation in the context of soil, land degradation, water and biodiversity, through various ministerial orders. For instance, Ministerial Order No. 14242 (15 December 2011) assigns the Office of Agroforestry and Restoration of Degraded Land (BARTD) the task of using mechanical and biological methods to recover saline and acidified soils (Art. 9). Additionally, Ministerial Order No. 8079 MEPN/DCS (1 August 2011) establishes the Joint Coordination Committee of the Capacity Building Project for the Control of Land Degradation and the Promotion of its Valorisation in Degraded Soil Areas (CODEVAL) and outlines its responsibilities for budget allocations in regional and rural councils and supporting the financing of activities to combat land salinisation. The National Strategy & Action Plan for Biodiversity (CBD), published by the Senegalese Ministry for Environment and Sustainable Development, recognises and addresses the impact of salinisation as a significant contributor to biodiversity loss.

Relevant literature

- Soil salinity assessment and coping strategies in the coastal agricultural landscape in Djilor District, Senegal by Thiam *et al*. (2019)
- Monitoring land use and soil salinity changes in coastal landscape: a case study from Senegal by Thiam *et al*. (2021)
- Senegal – land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for regional development, jobs, and food security by Faye *et al*. (2021)
- Vegetation change, tree diversity and food security in the Sahel: A case from the salinity-affected Fatick province in Senegal by Sambou (2016)

4.2.9 Somalia

Somalia is generally considered an arid and semi-arid country and is strongly affected by salinity. In the Horn of Africa, Somalia ranks the most affected country by groundwater salinity (Araya *et al*., 2023). Compared to the extent of Somalia's vulnerability to salinity, there have been relatively few analyses that have adequately mapped and assessed the problem in the country.

Key facts

- Changes in temperature and precipitation patterns, rising sea levels, increased evaporation, and the salinisation of soil and water sources have disrupted the water cycle, resulting in reduced water availability and heightened water insecurity (Ali *et al.*, 2023). The consequences of water quality changes are particularly impacting rural regions, where the availability of safe drinking water is already constrained (Ali *et al.*, 2023).

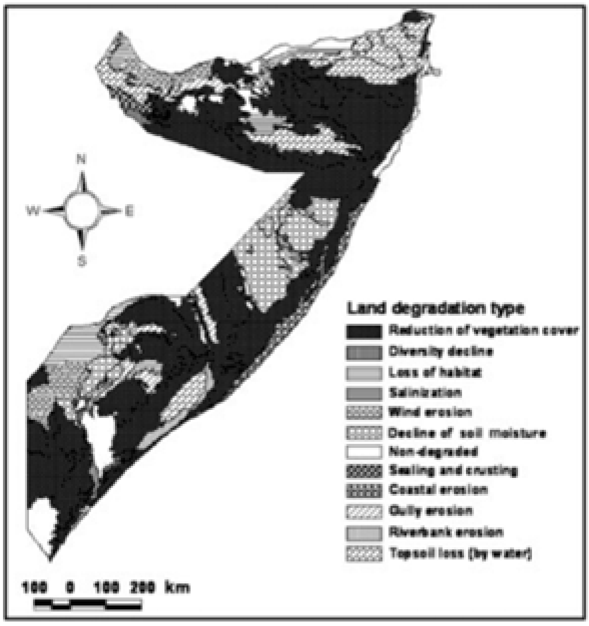

Figure 12 Prevalent types of land degradation in Somalia based on expert opinion (Omuto et al., 2011)

- The stresses posed on water resources resulted in heightened salinity and reduced water accessibility for purposes such as irrigation and other applications (Ali *et al.*, 2023).
- Impacts of climate change also caused increased variability in precipitation and reduction in water availability respectively, causing higher river salinisation in one of

the most important and strongly used water sources in Somalia, the Shabelle River (Ali *et al*., 2023).

- Salinisation was observed in the floodplain of Somalia's Juba River, in addition to other land degradation types such as river-bank erosion along the Shabelle River (Omuto *et al*., 2011).

Policy insights

Somalia lacks national policies directly addressing salinisation, but the issue receives attention in reports tied to international agreements. Notably, the National Biodiversity Strategy and Action Plan (NBSAP) under the CBD or the Country Report under the Land Degradation Neutrality Target Setting Process in Somalia (2020) address salinity concerns. The latter emphasises, for example, the importance of sustainable land management interventions, including mapping soil salinity. Proposed actions include conserving the indigenous agricultural varieties, diversifying agricultural crops, and promoting the cultivation of salt and drought-tolerant varieties.

Relevant literature

- A framework for national assessment of land degradation in the drylands: a case study of Somalia by Omuto, Balint & Alim (2011)
- Examining the impact of climate change on water resources in Somalia: The role of adaptation by Ali, Kassem & Gökçekuş (2023)

4.2.10 South Sudan

The Republic of South Sudan is a landlocked country in eastern Central Africa with a tropical climate (*World Bank Climate Change Knowledge Portal*, n.d. c). The state of scientific research for South Sudan is characterised by a general lack of data (Goes, 2022). Apart from a study by Goes (2022) assessing the current state of knowledge on groundwater in Southern Sudan, with a particular focus on Lakes State in the central region, there is little analysis available.

Key facts

- According to Goes (2022), the primary Umm Ruwaba aquifer in Lakes State generally offers good water-resource potential, characterised by low salinity and nitrate levels. However, in some regions, groundwater potential is limited due to deep piezometric levels, low transmissivity, and brackish salinity.
- Published literature indicates the presence of saline groundwater in north-eastern South Sudan, possibly associated with a concealed saline lake (Goes, 2022).

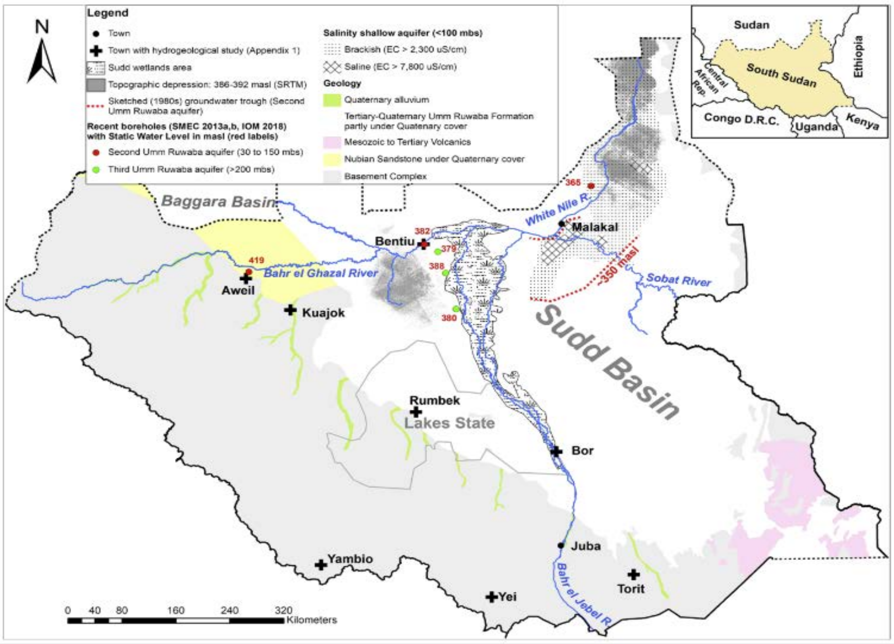

Figure 11 South Sudan hydrological map (Goes, 2022, p. 1036)

Policy insights

Our research on policies addressing soil and groundwater salinisation in South Sudan reveals a notable absence of specific regulatory measures. Salinisation is briefly mentioned in the context of water resource management in the South Sudan Water Policy (2007), which emphasises the urgent need for awareness raising to mitigate the environmental impacts of mismanagement, including salinisation. However, concrete regulatory provisions addressing salinity concerns are notably lacking in the current policy framework.

Relevant literature

- Review: Assessment of the aquifers in South Sudan with a focus on Lakes State by Goes (2022)

4.2.11 Sudan

Sudan has a wide range of climatic zones. Agriculture is a major part of the economy and provides about two-thirds of the population's livelihood (ICRC Climate Centre, 2021). Salinity varies from slight to strong across the country (see Figure 12), and salt-affected soils are relatively well studied by scientific research. For example, there are studies on salt tolerance and the effects of salinity on some agricultural crops (Ibrahim *et al*., 2013).

Key facts

- Sudan's salt-affected soils cover regions such as the White Nile, North Gezira, Khartoum state, and extend across the River Nile and the Northern states. Elmubarak's study (2007) identified approximately 268,636 ha in these regions as affected by salinity and/or sodicity. Despite these findings, there is still a considerable research gap and reclamation efforts related to salt-affected soils in Sudan (Abdelwahab, 2022).

- In Sudan, the salt tolerance of the tested crops was ranked as follows: Purslane (Portulaca oleracea) was the most tolerant, followed by Abu Sabeen, Pearl millet, Roselle and Okra, the most sensitive. Soil salinity is due to factors such as land use and saline irrigation water, and requires identification of salt types, chemical treatment and leaching for correction. Effective strategies include selecting salt-tolerant crops, using appropriate irrigation methods and managing groundwater levels to improve soil health and increase production (Sabir Ali *et al.*, 2019).
- Several studies indicate that the impact of salinity on agriculture is becoming apparent, particularly in irrigated areas where soil and water salts accumulate, potentially leading to secondary salinisation of previously non-saline soils (Abdelwahab, 2022). This problem is expected to worsen with population growth, increased land and water use, and the activation of previously underutilised resources. Ibrahim *et al*. (2013) highlights that effective management of both the physical and biological aspects of saline agriculture is critical to increasing production without exacerbating existing problems.

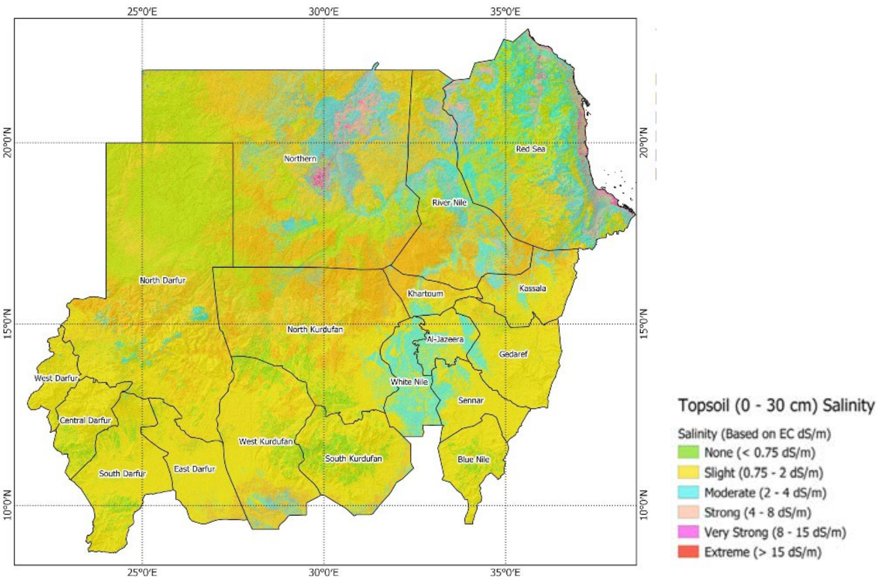

Figure 12 Sudan Topsoil salinity map (Ibrahim et al., 2013)

Policy insights

While Sudan lacks a dedicated salinity management policy, salinisation is addressed through water management policies. Sudan's 2016 National Adaptation Plan outlines strategic adaptation measures, including the establishment of desalination stations and water testing laboratories along the Red Sea, the construction of underground dams, and the improvement of water harvesting techniques. In response to soil salinity problems, boreholes for drinking water are recommended in low-lying areas. The report also formulated adaptation measures for saline groundwater in Gezira state, emphasising proper planning, awareness raising and capacity building for users, and technological improvements for community water storage systems. The country's Fourth National Report to the CBD (2009) proposes research into salt-tolerant plant species for biosaline irrigation along the Red Sea coast, using seawater without desalination to produce animal feed for nomadic pastoralists to improve their livelihoods and reduce poverty. The Ministry of Agriculture and Natural Resources, under the Sudan Sustainable Natural Resources Management Project (SSNRMP3), recognises salinisation as an impact of small-scale irrigation in its updated ESMF for 2020, and recommends measures such as avoiding waterlogging and using mulched soil surfaces to reduce evaporation.

Relevant literature

- A Review on Reclamation and Management Practices of Wind Erosion and Salt – Affected Soils of Sudan by Abdelwahab (2022)
- Monitoring, Predicting and Quantifying Soil Salinity, Sodicity and Alkalinity in Sudan, Using Soil Techniques, Remote Sensing and GIS Analysis, Case Study: University of Khartoum Top Farm by Ibrahim *et al*. (2013)
- Salt Tolerance and Effects of Salinity on some Agricultural Crops in the Sudan by Sabir Ali *et al*. (2014)

4.2.12 The Gambia

The Gambia is a West African country bordered by Senegal. It is characterised by a long, narrow land mass divided by the Gambia River. The country is strongly affected by salinisation due to seawater intrusion. While some studies delve into the impacts of saline-water intrusion on the lives of Gambian rice farmers (Bagbohouna *et al*., 2018), or Meanwhile Sambou & Ceesay (2023) conduct an in-depth analysis of climate change as a catalyst for natural resource conflict in Sambang, The Gambia (Sambou & Ceesay, 2023), experts report that a lack of data and resources is hindering further assessment by public bodies.

Key facts

- The Gambia River is an important source of freshwater for irrigation in tidal rice farming. However, the river is severely affected by saltwater intrusion due to sea level rise, temperature increases and reduced rainfall as a result of climate change (see Figure 13, Bagbohouna M'koumfida *et al*., 2018).
- The historical and ongoing challenges faced by lowland rice farmers in The Gambia have had a negative impact on rice production. Gambian rice farmers who rely on this water source have experienced low rice production affecting their livelihoods and food security and leading to abandonment of fields (Bagbohouna M'koumfida *et al*., 2018).
- Factors such as the disappearance of freshwater swamps and soil salinisation are contributing to the decline in national rice production, leading to dependence on rice imports and potential externalities of food insecurity and vulnerability to global market fluctuations (Bagbohouna M'koumfida *et al*., 2018).
- The effects of climate change, including sea-level rise, are closely linked to the degradation of essential natural resources. For example, salt intrusion (salinity) often reduces the fertility of agricultural land, affecting the performance and productivity of crops that are predominantly grown in wetlands (Sambou & Ceesay, 2023).

Expert insights

Salinity hotspots:
- Coastal areas
- River deltas (seasonal movements of the salt front; some regions are constantly affected, others fluctuate)
- Greater Banjul area

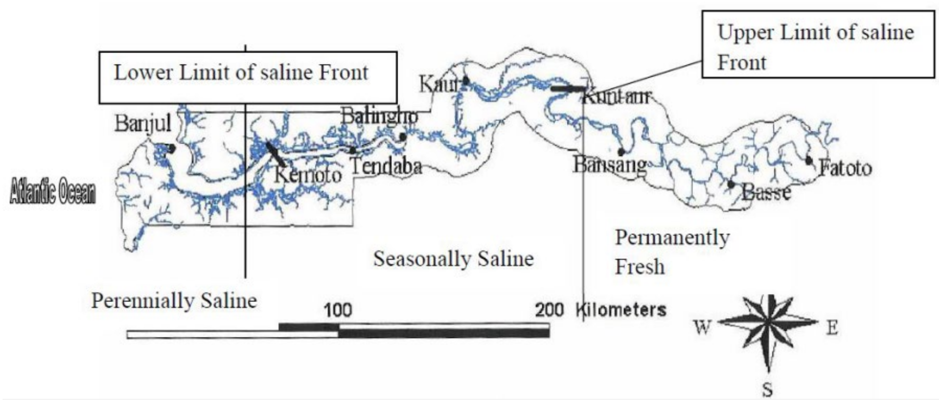

Figure 13 Salinity in The Gambia (Bagbohouna M'koumfida et al., 2018)

Policy insights

Salinisation in The Gambia is addressed through policies on soil, land degradation, biodiversity, and water. For example, The Gambia's National Agricultural Investment Plan, mentioned in the Agriculture and Natural Resources (ANR) Policy (2017-2026), sets a policy goal of improving "seasonally saline tidal swamps for rice production". In addition, the country addresses the impacts of salinisation on biodiversity in its National Biodiversity Strategy and Action Plan (2015-2020), among its planned activities under Aichi Target 15.

Relevant literature

- The Impacts of Saline-Water Intrusion on the Lives and Livelihoods of Gambian Rice-Growing Farmers by Bagbohouna M'koumfida, Yaffa & Bah (2018)
- An In-Depth Analysis of Climate Change as a Driver of Natural Resource Conflict: A Study in Sambang—The Gambia by Sambou & Ceesay (2023)

4.3 Key findings on the 12 focus countries

After reviewing literature for all the 12 focus countries, some overarching conclusions can be made. The literature review of soil and groundwater salinity studies in our focus countries reveals disparities in the state of scientific knowledge available for each country. Countries in Western Africa, such as Senegal and Burkina Faso, and in East Africa, such as Kenya and Ethiopia, have been relatively well studied. In contrast, more central countries such as Mali or Chad lack comprehensive analyses (see Table 4 & Figure 14).

It is also striking that there is a wide range of estimates of the extent of salinity, due to differences in measurement methods and imprecision of the data. To understand the true extent of soil and groundwater salinity in the 12 focus countries and subsequently take effective adaptation and mitigation measures, standardised and more accurate assessments and studies are needed.

Table 4 Table of the key findings from the country profiles

	Salinity issues	**Available knowledge**	**Policies in place**
Burkina Faso	🟡	🟢	🟢
Chad	🟡	🔴	🔴
Ethiopia	🔴	🟢	🟢
Kenya	🟡	🟢	🟢
Mali	🟡	🔴	🟡
Mozambique	🔴	🟡	🔴
Niger	⚪	🟡	🟡
Senegal	🔴	🟢	🟡
Somalia	🔴	🟡	🟡
South Sudan	⚪	🔴	🔴
Sudan	🟡	🟢	🟡
The Gambia	🔴	🟡	🟢

Salinity issues	Available knowledge	Policies in place
🔴 Severe	🔴 Little	🔴 Little
🟡 Moderate	🟡 Medium	🟡 Medium
🟢 Slight/none	🟢 Much	🟢 Much
⚪ No data available	⚪ No data available	⚪ No data available

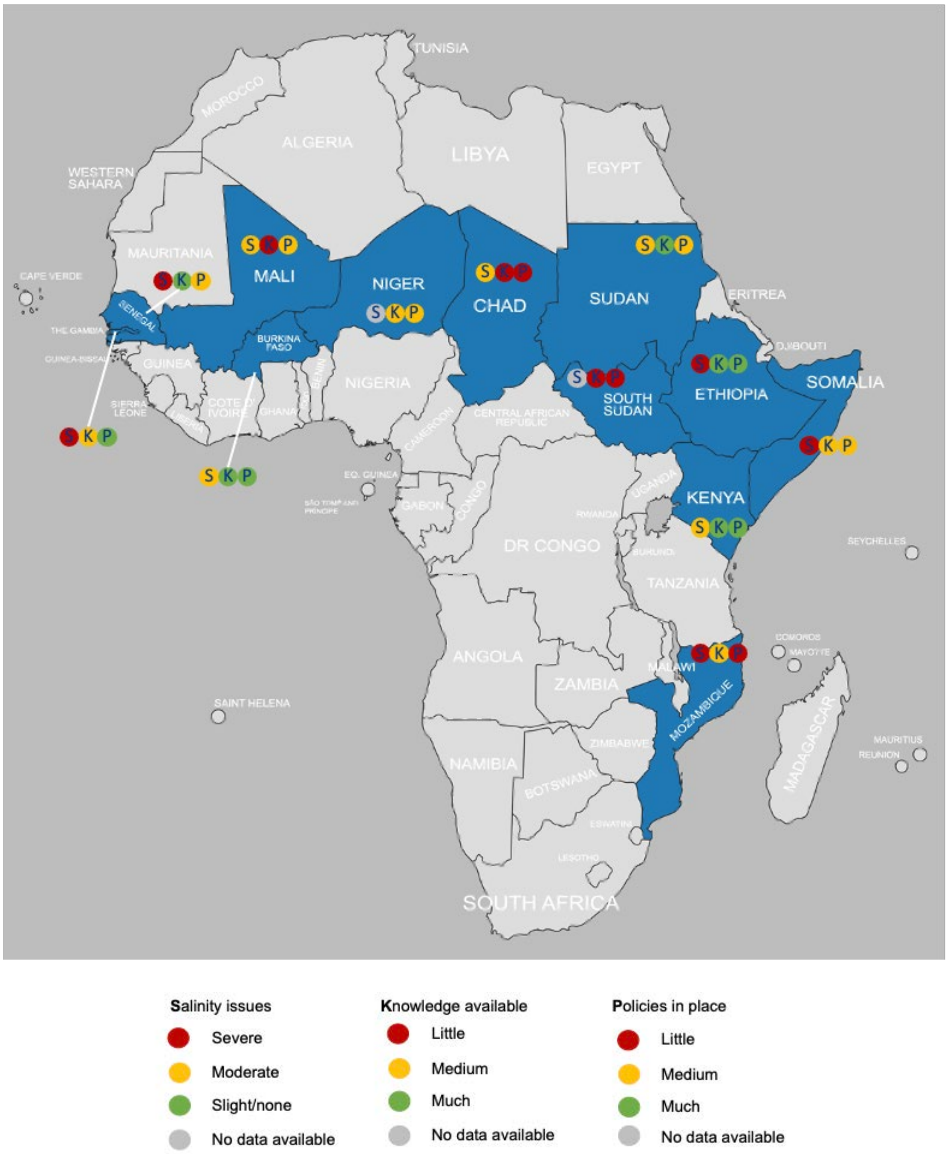

Figure 14 Map of the key findings from the country profiles

Further, the literature review shows that salinity and salinisation are commonly observed in coastal areas and river deltas. Contrary to this assumption, which is based on limited research and data, non-coastal countries such as Ethiopia are also experiencing severe salinity problems, highlighting the importance of salinity in arid and semi-arid inland regions. This challenges the misconception that salinity is primarily a problem in coastal areas and river deltas. Therefore, more scientific research and data collection is needed to accurately assess the impact in inland areas.

The analysis of policies on salinisation, in the context of soil, water, biodiversity, and land degradation in the 12 focus countries indicates a scarcity of national regulations directly targeting salinisation. Nevertheless, salinisation is frequently referenced in reports under international agreements on biodiversity conservation or desertification prevention. Table 5 illustrates the distribution of salinisation considerations within policies under the above-mentioned keywords.

Table 5 Distribution of salinisation considerations within policies under soil, biodiversity, water, and land degradation

	Soil	Biodiversity	Water	Land degradation
Burkina Faso				X
Chad		X		
Ethiopia	X		X	X
Kenya	X		X	X
Mali	X		X	X
Mozambique				
Niger	X	X		
Senegal	X	X	X	X
Somalia				X
South Sudan			X	
Sudan			X	
The Gambia	X	X	X	X

5 Impacts of salinisation: Regional Level

Salinisation of soil and groundwater resources not only impacts the environment, but can also have economic, social, and cultural consequences. Understanding the impacts of salinisation is therefore essential not only for farmers and pastoralists, but also for policy makers and researchers in order to develop effective adaptation strategies for sustainable agriculture and food security. As agriculture is a key sector for development and economic growth, especially in African countries (Clute, 1982), understanding the economic and environmental impacts of salinisation can be beneficial in developing effective policies to mitigate losses, sustain the incomes and livelihoods of people involved in the agricultural sector, protect natural resources, and ensure economic stability in affected regions. In addition, knowledge of the social and cultural impacts of salinisation is essential to strengthen the resilience of affected communities and to address the social and cultural challenges associated with salinisation. These can span from the threat of displacement of farmers due to increased land unproductivity and thus causing climate migration, to changes in traditional practices, and dealing with the effects of salinity on human health.

In this chapter, we present the economic, environmental, social, and cultural impacts of salinisation across five of our focus countries (see Table 7). These countries were selected based on the respondents we engaged with and conveniently encompass four of the most affected countries in the region. We highlight the interconnectedness of these impacts, offering insights into the challenges and opportunities for adaptation that arise. The assessment of the current and future impacts of salinisation in sub-Saharan Africa is based on interviews with experts and extension officers working in the field of salinity and salinisation. These have expertise on our focus countries Ethiopia, Kenya, Mozambique, Senegal, and The Gambia (see Table 6).

Table 6 Overview of Interviewees

Interviewee Code	Function	Organisation	Countries of expertise
Int#01	Specialist Saline Agriculture	The Salt Doctors, The Netherlands	Kenya, Senegal, Mozambique
Int#02	Project Manager - Saline Agriculture Initiatives in Mozambique	Weltweit-Cooperative for the Promotion of Local Initiatives e.V., Germany	Mozambique
Int#03	Soil Scientist	National Institute of Agriculture, Mozambique	Mozambique
Int#04	PhD at the Water & Climate Risk and Environmental Policy Analysis department	Institute for Environmental Studies (IVM), Netherlands	Kenya
Int#05	Field Officer	PlantVillage organisation, Kenya	Kenya
Int#06	Chief Hydrologist	Department of Water Resources under the Ministry of Fisheries and Water Resources, The Gambia	The Gambia
Int#07	Laboratory Management Director	Haramaya University, Ethiopia	Ethiopia
Int#08	Irrigation Water Management Engineer and Retired Senior Researcher in EIAR	Ethiopian Institute of Agricultural Research (EIAR), Ethiopia	Ethiopia
Int#09	Policy Officer	Ministry of Agriculture, Nature and Food Quality, The Netherlands	Ethiopia

5.1 Economic impact

Salinisation has the most direct economic impact on agriculture, but other sectors of economy are also affected. Experts from all five countries highlight the consequences of salinisation on farming: an **increasing loss of yields**, poor crop growth, or complete yield failure due to high salinity levels, leading to an increasing **loss of productive lands**. These impacts limit the expansion of agricultural land and thus hinders the upscaling of agricultural production. For example, almost all interviewed experts report that large areas of arable land in their countries have been abandoned due to soil salinity. The restoration of this land is either no longer possible due to a too high salinity level or would require high investments by responsible public institutions. These investments are furthermore needed for developing more water efficient irrigation structures. A senior irrigation engineer with long-standing experience of salinity issues in Ethiopia attests to this:

"The government has to expand the irrigated area [...], but at the same time, it needs to consider the side effects of poor management of irrigation, mismanagement of irrigation [...]. It needs big investment in order to bring well developed irrigation structures (Int#08)".

With regard to other sectors of the economy, Gambian respondents indicated that in addition to salinity related challenges in agriculture, fisheries are also affected since reduced water quality in freshwater resources due to increased salinisation affects certain fish species. Given that agriculture is known to be not only crucial to a country´s food security, but also an essential sector for development and economic growth, especially in Africa (Clute, 1982), the economic impacts of salinisation can have far-reaching consequences for the pace and level of development and economic prosperity of affected countries. Salinisation therefore has economic impacts at community and national levels. Not only does it affect **farmers' incomes and livelihoods**, but it also increases the **cost of farming and maintaining critical irrigation infrastructure** and reduces **agricultural exports**.

Costs & losses

Cost estimates indicate for a total area of 16 million ha saline soils 8 billion US$ of costs for salt induced land degradation (Negacz & Vellinga, 2021)

Opportunity costs	Loss of agricultural income or alternative activities
Production losses	Crop response function to salinity
Replacement costs	Preventing and restoring land degradation
Transaction costs	Costs of developing and applying land and water management plans
Market prices	Groundwater recharge credits trading, land rents
Mitigation costs	Desalination plan

(Qadir *et al*., 2014)

Preventing salinisation would result in significant savings, in terms of avoided yield losses, mitigation and opportunity costs, understood as the value of the trade-off when making a decision. It can also be thought of as the additional income that would remain if the soils were not saline (Negacz & Vellinga, 2021).

5.2 Environmental impact

In affected countries, salinisation has profound **effects on water quality**, reducing the availability of good-quality freshwater which exacerbates the issue of water scarcity. Furthermore, the interviews revealed **losses of freshwater ecosystems**. Thus, salinity also impacts **biodiversity**, as it affects some plant and fish species. Regarding environmental consequences of salinisation, it is notable that all respondents highlighted the exacerbation of the problem due to climate change. However, the consequences of climate change vary among the five focus countries. What is particularly noteworthy is the heightened extremes, encompassing elevated temperatures, diminished rainfall, prolonged drought seasons, and, in various regions, intensified rainfall, floods, and an increased likelihood of recurrent events such as cyclones, as consistently emphasised by the interviewees. In response to the question about potential future impacts of salinity in sub-Saharan Africa, one interviewee provided the following perspective:

"In sub-Saharan Africa, desertification has been increasing due to several factors of which climate change, population growth that leads to deforestation and land degradation are the major ones. These factors all increase evaporation from soil leaving salts in the surface soil or in the root zones. Then high concentration of soluble salts in soil will negatively affect plant growth and subsequently leads to decline in agricultural productivity and food insecurity (Int#07)".

5.3 Social impact

The economic and environmental impacts of salinisation are closely linked to the social impacts of the problem. The decline in crop yields and available arable land not only poses a threat to the food security but also threatens the **livelihoods of numerous smallholder farmers and pastoralists** in Africa. The effects of salinisation on the agricultural sector places them in a situation where they face an increasing risk of losing their means of subsistence and income which contributes to the **rise in poverty**. Moreover, certain interviewees have highlighted a surge in **health issues** attributed to the salinisation of freshwater aquifers upon which local communities rely. For instance, dental problems of individuals in salt-affected areas in Kenya have been reported, which result from the salinisation of their drinking water.

Furthermore, a Gambian expert, working as chief hydrologist at the Department of Water Resources under the Ministry of Fisheries and Water Resources, provides the following insights on future social impacts of salinity in The Gambia:

"We will lose a lot of freshwater ecosystems that are going to impact on the local communities that are depending on freshwater ecosystems. For their survival. And then it is going to impact their health. Also, their source of income [...]. It can impact other sectors like education of children who have to be involved in fetching water from very far locations or even the cost of supplying a water system to a village or community due to this fact (Int#06)".

An Ethiopian salinity expert reports that significant population growth is exacerbating the challenges. He explains that when the population was smaller (around 30 to 40 million), salinity was not as much of a concern as it is today, and irrigation was not considered a significant factor. *"[The] rainfed area was sufficient to feed the available population."* However, with the current population growth (approaching 120 million), a change in perspective is crucial. The expert stresses the importance of a proper irrigation water management plan and warns that without one, salinity could render most irrigated farms unproductive within the next 5 to 10 years:

"...currently the population is increasing [...]. Considering irrigation, most irrigated farms will go out of production in a few years because there is no plan how to manage irrigation water. [...] If there is no proper management of irrigation water, it will go [out of production] in 5 to 10 years due to salinity. So, there is a need to consider that sustainable production of agriculture is required because population is increasing, so it needs attention, great attention to consider salinity and the proper management of irrigation water (Int#08)".

5.4 Cultural impact

Cultural impacts of salinisation are interconnected with economic, environmental, and social ones. The effects of salinisation on the agricultural sector ask for **shifts in traditional agricultural practices**, potentially altering established traditional practices and cultural norms. Moreover, the depletion of arable land might force smallholder farmers to change their profession, leading to additional changes in livelihoods and potentially triggering climate migration. One of the experts emphasises that the land loss may concentrate people into smaller areas (Int#05), which could potentially lead to **stakeholder conflicts and social tensions**, particularly in the face of endangered food security, increasing population growth and poverty.

Table 7 Impacts of salinisation across 5 of the focus countries

IMPACTS	Economic	Environmental	Social	Cultural
The Gambia	X	X	X	
Senegal	X	X	X	
Ethiopia	X	X	X	X
Mozambique	X	X	X	
Kenya	X	X	X	X

5.5 Responses to salinisation and adaptation strategies

The analysis of regional responses to salinisation of soil and water revealed some similarities but also some differences among the focus countries. In Ethiopia, the situation is quite clear:

"If [farmers] get assistance, they will adapt [to salinity], otherwise, they will abandon [the land] (Int#08)".

Based on the interviews conducted with Ethiopian experts, the support already provided includes **educating farmers about salt-tolerant crops** and **promoting the use of salt-tolerant grass** for livestock, citing several benefits. This approach is promising as an adaptation strategy, particularly given that nomadic pastoralists engaged in vegetable and livestock production are often located in salt-affected areas of Ethiopia. Additionally, it was noted that scientists in Ethiopia are engaged in improving the salt tolerance of crops, with **breeding programs** for various salt-tolerant crops such as sorghum, maize, several cereals, and cotton. The adaptation strategy of **soil moisture conservation** was also mentioned. However, its effectiveness has fallen short of initial expectations. One of the Ethiopian interviewees stated:

'There are interventions, but impacts of such interventions were not significant when compare with the extent of the problems (Int#07)'.

In Kenya, many farmers are trying to adapt to salinisation through improved **drainage**. This approach allows water to effectively leach away salt when it rains. Similar as in Ethiopia, saline soils and grasslands are sometimes used for livestock, and respondents also reported that **saline water is used** for practices such as washing clothes. The interviews also revealed that several soil improvement practices are undertaken in Kenya, such as the production and **application of biochar**. The use of lime and calcium carbonate as a salinity mitigation strategy also appears to be known, but little information is available on their actual use. In Kenya, people are also aware of the potential of **salt-tolerant crops** to adapt to salinisation. Common crops used as part of this strategy include Swiss chard, beets, cabbage, and other vegetables. There have also been a number of interventions by external actors, such as the **promotion of composting methods**, using either prunes or catfish effluent to water the compost, or the **development of agroforestry**. However, as reported by a representative of a non-local company using such methods, these interventions are often small-scale.

'The prunings of the food forest are being cut smaller and made into compost and the water of the catfish [is used] to keep the compost wet, and because of that it composts faster. [...] Adding compost to soil is a very good adaptation strategy to salinity (Int#01)'.

In Mozambique, several adaptation strategies have been introduced by external entities through workshops or research projects. These strategies include again the **use of organic amendments and compost**, this time incorporating chicken and green manure, biochar, and other locally available amendments. The main component of one notable project was the introduction of a portable soil sensor equipment to enhance **real-time salinity assessments** and **monitoring** within the local extension service. Additionally, a local initiative aimed to map salinity using remote sensing and conducted tests to determine the salt tolerance of crops like falcon, sorghum, millet, barley, and cowpea. However, since these initiatives often happened within small-scale research projects, the interviews revealed that farmers commonly tend to abandon land with too high salt-levels, as an adaptation strategy. One of the interviewees from Mozambique recommends:

'On the level of the farmers, I think if you could provide more information in terms of the actual extent, the type of salinity, etc. And [if] you have knowledgeable advisory services which could then advise based on that information, I think that would be already pretty helpful. I think the right agronomic approach really differs from production system to production system on the farm level. I think it's difficult to generalise. But also on a countrywide scale, [...] the first step really would be to have a better database, in terms of extension of the salinity problem on a country scale and [...] a better characterisation of the type of salinity. So, some sort of mapping approach (Int#02)'.

For Senegal, only a limited amount of information could be gathered on adaptation strategies. However, a representative of an initiative implemented by an external actor reported on the usage of **mulching** to reduce the evapotranspiration and raised beds. Furthermore, advice was given to change **crops and irrigation methods**.

'In Senegal we have seen that they are aware of the problem, and they grow their crops on raised beds [...] but this was mostly in a Research Institute. [...] If you make a raised bed, [...] you can kind of micromanage where salts accumulate. If you use mulching, which is a layer of organic matter on top of your soil, you reduce evapotranspiration, so you reduce the loss of moisture. [...] So if you have measures in place that increase soil moisture or at least reduce the increase in evaporation that would help, and they know about those things in Senegal [...] (Int#01)'.

In The Gambia, the abandonment of land becomes common when increasing salinity-levels make it unusable. A notable observation from an interviewee highlight, that boreholes along riverbanks, initially used for drinking water, livestock, and irrigation, are abandoned due to the increasing salinity. Adaptation strategies piloted by public authorities include the attempt of **introducing salt-tolerant crops**. In addition, efforts are planned to reform regulations in the water sector and improve **data collection** to more effectively report on key Sustainable Development Goals (SDGs) indicators. Regarding one of the interviewed experts, these indicators encompass critical aspects like water stress, water productivity, and water use efficiency. However, the interviews revealed the need for support to realise these goals, mentioning a shortage of tools and funding for comprehensive data collection. A representative of the Department of Water Resources under the Ministry of Fisheries and Water Resources elaborates:

'... these are all areas that we want to focus [on], so that we can generate knowledge and also inform policy. But due to low data collection capacity [...] we are not able to fulfil this (Int#06)'.

5.6 Challenges and outlook

Interviews with extension officers and salinity experts on five of our focus countries identified diverse impacts of salinisation on the economic, environmental, social, and cultural fronts. These impacts pose challenges for farmers and pastoralists, policymakers, and international initiatives, addressing the issue. The impacts of salinity and salinisation are exacerbated by climate change and the diminishing availability of vital resources such as land, food, and fresh water, coupled with growing populations and rising demand, increases the potential for conflict between communities that depend on these resources. Social challenges such as political instabilities, poverty, corruption, general health issues, limited knowledge and low education levels interact with the potential of conflict and highlight the need to address salinisation impacts.

On the other side, economic challenges include poverty, a lack of financial resources, and the need for substantial investments and affect not only smallholder farmers but also companies depended on the agricultural sector. Insufficient resources for maintaining or improving infrastructure, like inefficient dikes and inadequate irrigation, exacerbate the situation. The region faces the risk of more and more land going out of production, without proper management, compounded by poor soil and water management practices in place. Governments and public authorities often lack resources to invest in necessary infrastructure, which was highlighted by an interview partner from Ethiopia who states that installation of drainage pipes to manage excess water and control groundwater might be an efficient adaptation strategy. However, due to economic constraints, undertaking such initiatives demands financial resources that the Ethiopian government currently lacks.

Adding to this, the interviews revealed a lack of a felt need for concentrated effort among public authorities. In Ethiopia, for example, the government focuses on expanding the irrigated area in order to meet the needs for a growing population. Considering the effects of bad irrigation management makes this task even more challenging. Culturally, challenges arise in implementing new, salt-tolerant crop varieties due to taste and preference considerations. Lastly, the analysis of the interviews uncovered certain technological challenges: The unavailability, low quality, or inconsistency of data in public institutions hampers informed discussions on salinisation. The absence of tools to measure salinity and technologies for managing and reclaiming salt-affected soils exacerbates the issue.

In conclusion, impacts of salinisation in sub-Saharan countries extend across the economy, environment, social, and cultural domains and are strongly interconnected. Together, they will not only affect smallholder farmers and pastoralists, but also companies and decisionmakers. The looming scenario of diminishing resources and increasing demand from a growing population not only poses risks to food security, but also increases the risk of conflict between users of these resources. Looking at the various challenges faced by the region, the far-reaching impacts emphasise the need for further research and concerted efforts on this pressing issue, even though some promising adaptation strategies already exist. Given the interconnectedness of impacts, it is also important to ensure that the problem is not exacerbated in the near future, which means that combined efforts are needed to develop effective adaptation and mitigation strategies.

6 Initiatives and Networks: International level

In this chapter we shift our focus from the national and regional perspective on the problem of salinisation in sub-Saharan Africa to a closer examination of actions and interventions undertaken on the international level. Therefore, we present an in-depth analysis of the governance landscape of ICIs which are active in our selected countries. We delve deeper into their geographical distribution among these nations and the location of the ICI'S secretariats. In addition, we analyse initiative functions, how these vary across different actor constellations, salinity-related themes they address, and SDGs they aim to achieve. Lastly, we showcase funding and monitoring schemes implemented by the initiatives and compare them to global and regional cost estimates of salinisation impacts on agriculture. The objective is to provide a comprehensive overview of the institutional landscape of salinity governance in the sub-Saharan region, aiming to both highlight successful approaches to address salinisation and identify areas that require further development and attention.

6.1 Geographical distribution

Mozambique takes centre stage as a focus country of the ICIs, as 13 initiatives (43.3%) involve Mozambique in some way. Senegal follows with 9 initiatives (30.0%) and Kenya with 8 initiatives (26.7%). Chad, Somalia, and South Sudan are among the least focused on countries, with 2 (6.7%) initiatives active in Chad and only 1 (3.3%) focusing on Somalia and South Sudan respectively (see Table 8 & Figure 15). On a positive note, in each of our focus countries at least one initiative is already active. However, there is a large variation in the number of ICIs focusing on these countries.

Table 8 ICIs across focus countries

Country	Number	Percentage
Somalia	1	3.3%
South Sudan	1	3.3%
Chad	2	6.7%
Sudan	3	10.0%
Mali	4	13.3%
Niger	4	13.3%
Burkina Faso	5	16.7%
Ethiopia	6	20.0%
The Gambia	7	23.3%
Kenya	8	26.7%
Senegal	9	30.0%
Mozambique	13	43.3%

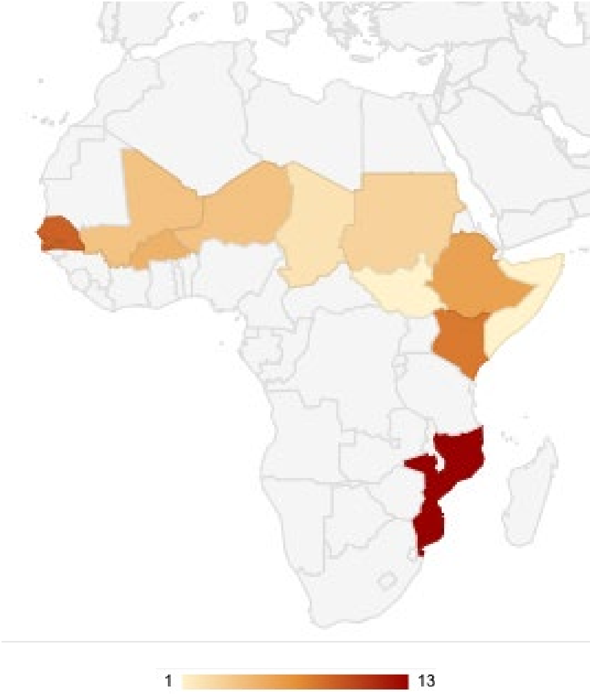

Figure 15 Map of geographical Distribution of ICIs across the focus countries

These findings align with our literature review, indicating that there are countries with a greater availability of scientific knowledge on salinisation, mirroring the concentration of ICIs in those regions. On the other hand, there are countries where little information on salinisation is available, such as Chad, Mali, and South Sudan. Correspondingly only a few ICIs are focused there.

Examining further the geographical location of the ICIs headquarters enables us to make assumptions about the location, from where actions are managed. Most ICI secretariats are located in the Netherlands (24.1%), followed by Germany (13.8%), Australia (13.8%), and Dubai (10.3%). While even a few ICIs have their headquarters in Asia, only two of the ICIs are organised from Africa (6.9%) (see Table 9 & Figure 16).

Table 9 Location of secretariats

Location of secretariats	Number	Percentage
Philippines	1	3.4%
France	1	3.4%
Austria	1	3.4%
Spain	1	3.4%
United Kingdom	1	3.4%
Italy	2	6.9%
Kenya	2	6.9%
Dubai	3	10.3%
Australia	4	13.8%
Germany	4	13.8%
The Netherlands	7	24.1%

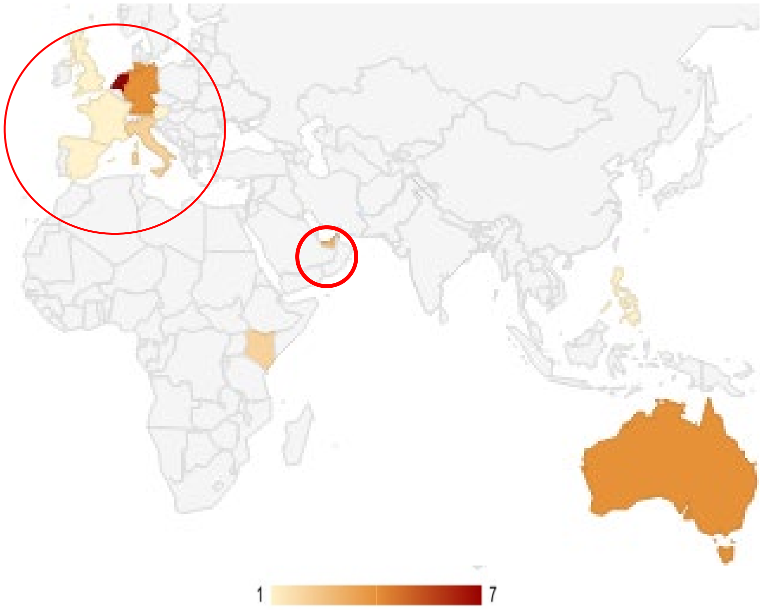

Figure 16 Map of location of ICI secretariats

It is important to critically reflect that even though the ICIs focus with their activities on African countries, they are mainly organised out of Europe, Australia, or Dubai. This illustrates a strong North-South imbalance, which could be explained by a strong dominance of development projects among the collected ICIs.

Managing initiatives with a certain geographical and cultural distance to their action areas holds potential consequences. For example, Lund & Baudouin (2023) find that traditional agrarian economies and the increasing pressure on smallholder farmers and pastoralists due to the growing influence of capitalism in agriculture, land grabbing, and expropriation by agribusiness, can be neglected, particularly in relation to development projects in Africa. In addition, their research highlights cases, such as in Ethiopia, where agricultural development has been a process of marginalisation and exploitation for pastoralists (Lund & Baudouin, 2023). In order to mitigate these risks, it is crucial to shift the organisation and steering of such initiatives more towards the regions in which they operate. Despite the challenges encountered, involving local and regional partners in these efforts can enhance the effectiveness of these initiatives, as these actors are inherently motivated to address social and environmental concerns for a variety of reasons (USAID, 2015).

Another striking point is the dominance of the Netherlands, which hosts 24.1% of all ICI secretariats. While we recognise the potential for bias in our findings due to the research being conducted in the Netherlands, the results should not be attributed only to this bias. Indeed, the Netherlands has a high level of expertise in water management, a willingness to develop innovative solutions to climate change impacts (Negacz *et al.*, 2022), and is active on the international salinity governance scene. Yet, this pattern underscores the impact of a single nation in shaping objectives and strategies for global salinity governance, potentially strengthening prevailing Western hegemonic structures. It is therefore crucial to evaluate the motivations and aspirations driving this strong involvement.

6.2 Functions of initiatives

In this sub-chapter we categorise 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).

Most of the initiatives perform, either jointly or exclusively, operational functions (83.3%). The second most, either jointly or exclusively, performed function is information sharing and networking (73,3%). Only 3.3% of the ICIs hold financing functions and none hold standards and commitments functions (see Figure 17). It is notable that none of these ICIs hold exclusively information and networking functions, while 26.7% perform exclusively operational functions. However, more than half of the ICIs (56.7%) perform jointly operational and information and networking functions.

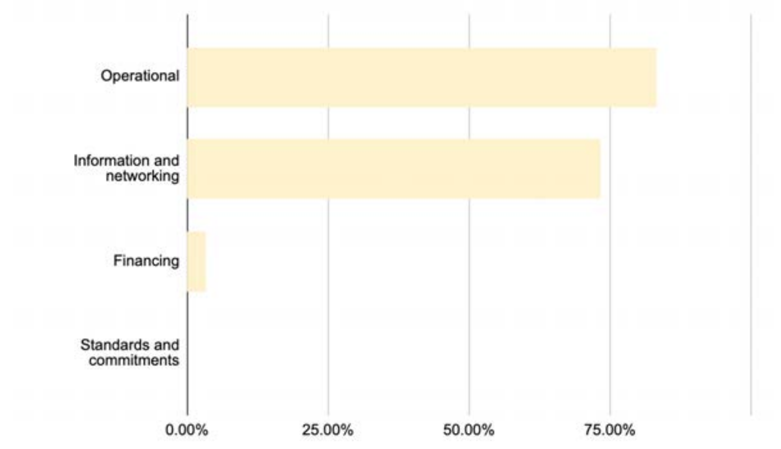

Figure 17 ICIs by governance functions

Comparing the relation between the actor constellation and the functions of ICIs, we find that ICIs that carry out operational functions mostly are coalitions of exclusively public actors. However, operational functions are also performed by partnerships of public and civil society actors or public-private-civil society collaborations (Appendix B.2). On the other hand, ICIs focusing on information and networking functions are predominantly led by public-private partnerships, closely followed by ICIs involving solely public actors. It is worth noting that only one ICI performs the financing functions, and it operates within the framework of a public-private partnership.

The strong emphasis on operational and information and networking functions among ICIs operating in sub-Saharan Africa could be traced back to the prevalence of development and research projects within the dataset. This trend is further underscored by the actor constellations (see Figure 18). While most of the ICIs are constructed as public-private partnerships (34.8%) or exclusively public partnerships (30.4%), there is a notable absence of ICIs exclusively composed of private actors, often associated with financing functions, in the database.

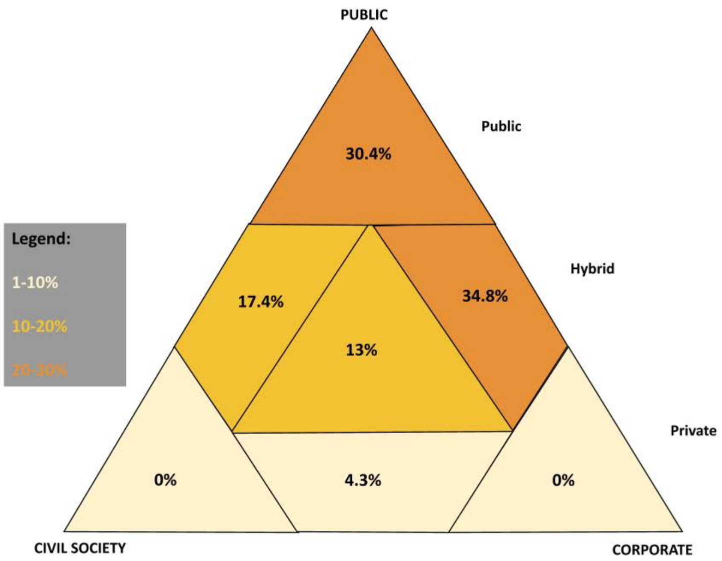

Figure 18 Governance triangle (adapted from Abbott and Snidal (2009a; 2009b, Abbott 2012)) for ICIs active in sub-Saharan Africa. The seven zones show the percentages of actor constellations within the initiatives analysed.

Comparing these findings to other analysed regions of salinity governance such as the Mediterranean and Middle East and North Africa (MENA) region, or the Central, South, and Southeast Asian region, the distinctive emphasis on operation activities and the insufficient focus on financial functions stands out (Negacz *et al*., 2022; Smaoui & *Negacz,* forthcoming). This trend aligns with previous research indicating that operational activities are frequently spearheaded by public entities (Visseren-Hamakers, 2013) and hybrid actor constellations (Widerberg *et al*., 2016; Sanderink *et al*., 2018; Arnau *et al*., 2017). However, to scale up saline agriculture and proactively address the impacts of salinisation in sub-Saharan Africa, a stronger focus on and commitment to financing and standard and commitment functions is required to be able to implement projects of a larger scale and longer duration, and to evaluate and monitor their progress and outcomes. Initiatives performing these functions are not only deficient in the sub-Saharan region but also in the Mediterranean and MENA region, and the Asian region as indicated by Negacz *et al*. (2022) and Smaoui & Negacz (forthcoming).

6.3 Focus on themes

The ICIs addressing salinisation in our focus countries focus more on adaptation to salinisation (25.3%) than on mitigation (9.6%). This is particularly interesting in the context of the observation that poor irrigation practices can lead to widespread salinisation (Chapter 3). Improved irrigation methods could therefore be a lever to prevent future salinisation. Furthermore, soil management and water management are among the most focused themes, with 24.1% and 19.3% of ICIs focusing on them respectively. Another interesting observation is that the ICIs tend to focus on the cultivation of conventional, salt-tolerant crops (18.1%), while halophytes (plants flourishing in saline environments) seem to be rather unpopular (2.4%), or perhaps not in line with regional needs and preferences, or there is still a lack of knowledge about them. This observation can also reflect a focus on increasing food production rather than diversifying diets with new crops. A rather under-represented topic is aquaculture (1.2%), although the interviews revealed that there may be potential in adapting shrimp and fish aquaculture to salinisation. The reason could be an inland location of some of the countries but also a lack of circular and integrated farming systems.

We further looked at the SDGs addressed either explicitly or descriptively in the websites or mission statements of the ICIs. Among all SDGs, SDG2 “Zero hunger” and SDG13 “Climate action” are the most addressed, with 16.3% and 14.3% respectively. SDG1 “No poverty” (12.2%) and SDG17 “Partnership for the goals” (11.2%) also receive notable attention. Other frequently addressed goals include SDG8 “Decent work and economic growth” (9.2%), SDG9 “Gender equality” (7.1%), and SDG4 and 12 “Quality education” (5.1%) and “Responsible consumption and production” respectively (see Figure 19).

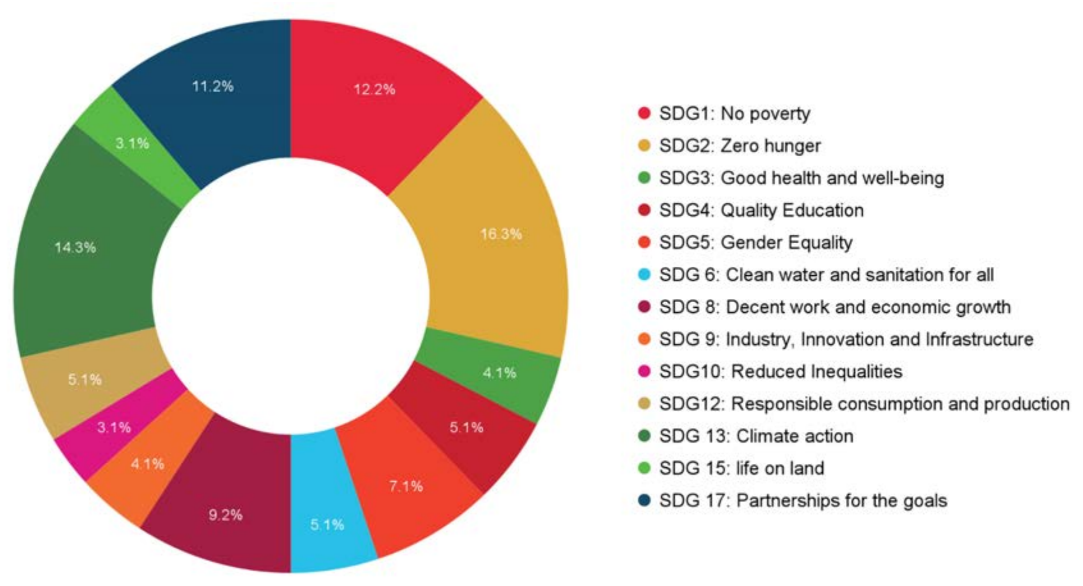

Figure 19 SDGs addressed by ICIs

The thematic focus of the ICIs on salinity adaptation is in line with SDG13. The focus on salt-tolerant crops, soil and water management is consistent with the objectives of SDG1 and SDG2. Our findings are consistent with previous research on SDGs related to saline agriculture, as shown by Negacz *et al*. (2022). However, while clean water and sanitation (SDG6) receives more attention in other regions, initiatives operating in sub-Saharan countries prioritise partnerships. The prominence of climate action (SDG13) is evident not only among ICIs addressing salinity, but also among those addressing other governance areas such as biodiversity (Kok *et al*., 2019), highlighting the impact of climate change on these governance aspects.

6.4 Funding and monitoring

Overall, 46.7% of ICIs provide information about their funding scheme. Within this subset, a significant 85.7% are transparent about their budget, while 92.9% disclose information about their funders. The financial scope of these ICIs ranges from approximately €41,000.00 to €20,000,000.00, resulting in a middle value of this distribution of around €1,300,000.00. The wide range and funding may be due to the different project durations, ranging from one to 21 years, but it also illustrates the wide variation in the financial resources available for such projects.

Comparing the funding variable results to global and regional cost estimates of salinisation impacts as highlighted in the introduction, a notable disparity emerges between the invested funds and the projected financial requirements in order to adapt and to mitigate salinisation. This suggests that existing investments in salinisation initiatives fall short of meeting the estimated costs, leading to substantial economic losses and profound socio-economic impacts.

When it comes to reporting and monitoring their activities, only 33.3% of the ICIs have a progress report available on their websites. This might also be related to the fact that some ICIs have been initiated quite recently and therefore, reporting might be published a bit delayed. Moreover, only 16.7% monitor their activities which accounts for only five of the ICIs. 30% define quantitative targets, for example to reclaim a certain number of salt-affected land. However, only 6.7% of these ICIs have monitoring frameworks in place, to track if these targets will be achieved.

7 Policy recommendations and conclusion

To summarise our findings and return to the research questions outlined in the introduction, we observe a significant disparity in the scientific knowledge of groundwater and soil salinisation across sub-Saharan countries. ***While coastal countries such as Senegal in West Africa and Kenya and Sudan in East Africa are relatively well studied, landlocked countries such as Mali or Chad lack comprehensive analysis***. In addition, interviews highlighted common problems of data unavailability and inconsistency, which pose challenges for knowledge provision and dissemination. When it comes to answering the second question of salinisation hotspots within countries, the literature review and interviews revealed that based on the available research ***salinisation mostly occurs in coastal areas and river deltas***. Reasons for this include seawater intrusion and seasonal variations in the salinity fronts of rivers, depending on the wet and dry seasons. However, as a landlocked country, Ethiopia presents a unique scenario where salinity studies are already well established and stands out within our scope as the most affected country. This indicates a lack of adequate research on inland salinity. Therefore, we cannot assume that the availability of more knowledge in coastal countries is necessarily a sign of greater salinity vulnerability. The lack of data availability and comprehensive knowledge on inland areas is therefore a major challenge in estimating salinity distribution across the region.

Salinisation has far-reaching economic, environmental, social, and cultural impacts in affected countries. These effects include the loss of crop yields and productive agricultural land, affecting the livelihoods and food security of communities. Climate change is expected to worsen and exacerbate these impacts if no action is taken.

This is where international cooperation initiatives have a crucial role in tackling the challenges of salinisation, particularly through strategies such as saline agriculture and the implementation of adaptation measures. In addition, the prevention of future salinisation through mitigation measures such as improved irrigation management was highlighted by interviewees. However, ***initiatives are still falling short of mitigating salinisation*****.**

The analysis of the governance landscape for saline agriculture in sub-Saharan Africa revealed that even though initiatives are active in all our focus countries, the quantity of ICIs varies widely among them. While ***ICIs primarily engage in operational, information, and networking functions – crucial for knowledge exchange and the implementation of pilot projects*** – greater involvement of ICI actors that provide funding, support the implementation of standards, and make long-term commitments is essential for the widespread and effective implementation of adaptation strategies. Finally, it became clear that there is a considerable ***gap between the investment needed to prevent the enormous economic losses caused by salinisation in this region*** and the funds available to finance such initiatives. This needs to be considered if salinisation is to be tackled properly to secure smallholder incomes at the local level and ensure economic growth and development at the national level.

Key findings in brief:

- **State of the art of the knowledge:** Salinity has been studied in several parts of the sub-Saharan region. Groundwater salinity has often been addressed directly, whereas soil salinity is often discussed in the context of general soil degradation analysis in sub-Saharan Africa. Especially, the region of the Horn of Africa seems to be well analysed so far. Lots of knowledge is available on coastal areas and river deltas, while sufficient analysis and evaluation on inland salinity is still lacking.
  - Well-studied countries: Senegal, Burkina Faso, Ethiopia, Sudan, Kenya
  - Moderately studied countries: The Gambia, Niger, Mozambique
  - Poorly studied countries: Mali, Chad, South Sudan

  Recommendations:
  - Conduct baseline research in the little studied countries and update and deepen analysis in the well-studied countries
  - Conduct research on inland salinity, especially in arid and semi-arid regions
  - Improve funding and adaptation measure in the well-studied countries
- **Affected areas and salinity hotspots**: Ethiopia, Senegal, and Mozambique have large surface areas of the salt-affected soils. On the contrary, for Burkina Faso and Sudan relatively low surface area is salinized. Mozambique lacks relevant policies even though the country is heavily affected by salinity

  Recommendations:
  - Encourage regional transfer of know-how and policy solutions
  - Support putting salinity on the policy agenda and design optimal instruments for local stakeholders
- **Impacts of salinity**: effects of salinity are mostly visible in the agricultural sector, but it affects the economic development of the countries, the land use, migration patterns and biodiversity of land ecosystems. On the farm level, we observe lower yields, increasing unemployment, widening gender gaps, and lack of opportunities for the youth.

  Recommendations:
  - Provide tailor made training to farmers and other affected stakeholders to mitigate or adapt to salinity, especially for the youth and women.
  - Consider Nature Based Solutions such as saline agriculture to address environmental goals and human well-being
  - Focus on mitigating costs of salinity and opening opportunities for additional income
- **Governance landscape:** Multiple initiatives for salinity are active in the region. They focus on operational activities, information sharing and networking. The initiatives are mostly led by public-private and public actors, with a strong focus on food and water security and climate adaptation. Accountability schemes are limited.

  Recommendations:
  - Improve monitoring and reporting of initiatives to increase their effectiveness
  - Support initiatives that perform financing functions and that support the introduction of mandatory compliance, measurement standards, activity

disclosures, and voluntary commitments to bridge the gaps and create financial incentives for the investors
- Involve more civil society and private actors to represent a wider range of stakeholders and have their voice heard.

These recommendations indicate future directions that can be undertaken by both practitioners and scientists. More research and practical projects are needed to prepare the region for the climate-proof saline future. Good solutions and promising innovations are already being implemented in some countries. Therefore, future efforts should focus on mutual learning, international knowledge transfers and on the ground actions.

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Appendix A Data collection

A.1 List of databases used for data collection and terms used in internet search

Databases	FAO partnership database, EU CORDIS database, European Commission LIFE public database, ICBA project database, RVO project database, GIZ database, CGIAR Initiative explorer, IFAD Rural Solutions Portal, SAI projects platform, UN SDG Actions Platform, African Development Bank Data Portal
Internet search areas & terms	Sub-Sahara, sub–Saharan Africa, food insecurity, food production, soil salinity, salinisation, irrigation with saline water, groundwater salinity, saline agriculture, water management, initiative, partnership, project, agriculture, climate change

A.2 List of keywords for semi-automated content analysis

Keywords	Salt-affected; salt-tolerant; saline; salini*; brack*; halophyte*

A.3 List of variables in the database

General information
Project name
Acronym
Umbrella organisation
Website
Last activity on website
Launch year
End year
Duration of ICI
Research project
Validation
Actor variables
Zone of the governance triangle
Research institution
Partnership
Number of actors
Funding
Funding scheme
Budget
Annual funding

Governance function
Standards and commitments
Information and networking
Financing
Operational
Geographical variables
Geographical focus among the 12 countries
Physical location of secretariats
Area of action location
Thematic focus
Salinity mitigation
Salinity adaptation
Halophytes
Conventional crops
Aquaculture
Water management
Soil management
Sustainable Development Goals addressed
SDG 1: No poverty
SDG 2: Zero hunger
SDG 3: Good health and well-being
SDG 4: Quality education
SDG 5: Gender equality
SDG 6: Clean water and sanitation for all
SDG 7: Affordable and clean energy
SDG 8: Decent work and economic growth
SDG 9: Industry, innovation, and infrastructure
SDG 10: Reduced inequalities
SDG 11: Sustainable cities and communities
SDG 12: Responsible consumption and production
SDG 13: Climate action
SDG 14: Life below water
SDG 15: Life on Land
SDG 16: Peace, justice, and strong institutions
SDG 17: Partnerships for the goals
MRV Variables
Quantitative targets
Monitoring framework
Public reporting
Source progress report
Annual reporting
External verification
Internal verification
Sanction provisions
Accountability index

A.4 List of initiatives

Acronym	Name	Link to website
ACCRUA	Adaptation To Climate Change In Rural And Urban Areas Of Mosambique (Acc Rua)	https://www.giz.de/projektdaten/projects.action?request_locale=en_GB&pn=201197722
AfSP	African Soil Partnership	https://www.fao.org/global-soil-partnership/regional-partnerships/africa/en/
AIWAP	Africa Irrigation and Water Project	https://africawaterproject.wordpress.com/
CARD	Coalition for African rice development	https://riceforafrica.net/about-card/
CIRAWA	Agro-ecological farming for resilient agriculture in West Africa	https://cordis.europa.eu/project/id/101084398
ESA	ESA Saline Agriculture Network initiative	https://welt-weit.org/en/project/esa-saline-agriculture-network/
GLOCAMSAL	Develop and implement a Global Campaign on Salinization	https://sdgs.un.org/partnerships/develop-and-implement-global-campaign-salinization
ICSPS	Improving Crop and Seed Production Systems under Sustainable Water/Irrigation Management in Sub-Saharan Africa	https://www.biosaline.org/projects/improving-crop-and-seed-production-systems-under-sustainable-waterirrigation-management
IHS	Impactcluster Horti Senegal	https://projects.rvo.nl/project/nl-kvk-27378529-pic22sn01/
IIWP	Increasing irrigation water productivity in Mozambique, Tanzania and Zimbabwe through on-farm monitoring, adaptive management and agricultural innovation platforms	https://www.aciar.gov.au/project/fsc-2013-006
INFA	Interfaces	https://www.zef.de/interfaces
NENA	Near East and North Africa Soil Partnership	https://www.fao.org/global-soil-partnership/regional-partnerships/nena/en/
RAMSAP	RAMSAP	https://www.biosaline.org/projects/rehabilitation-and-management-salt-affected-soils-improve-agricultural-productivity-ramsap
RESADE	Improving Agricultural Resilience to Salinity through Development and Promotion of Pro-poor Technologies (RESADE)	https://resade.biosaline.org/
RESADIJ	Contribution to the restoration of land affected by salinization in the locality of Djilor for a sustainable agriculture (Fatick Region)	https://www.climate-chance.org/en/best-pratices/restauration-salinization-fatick-region/

Acronym	Name	Link to website
SAFECOMAL	Feasibility study of Saline cultivation, adaptive water management and commercial agroforestry to improve crop yield and land degradation Kenya	https://projects.rvo.nl/project/nl-kvk-27378529-sb1sh18026/
SAKEN	Introduction of saline agriculture in Kenya with a focus on capacity building and socio-economic evaluation-	https://www.thesaltdoctors.com/kenya
SALIHORT	SaliHort	https://welt-weit.org/en/project/esa-saline-agriculture-network/
SALINPROVE	Mitigating groundwater SALINity impacts for imPROVEd water security in coastal areas under socio-economic and climate change	https://salinprove.un-ihe.org/home
SASEN	Strengthening education on climate smart and saline agriculture by training teachers to enhance food security in Casamance, Senegal	https://www.thesaltdoctors.com/senegal
SASUD	Sustainable agricultural development under saline conditions and climate change impact	https://www.thesaltdoctors.com/sudan
SEEQ	Seed Equal	https://www.cgiar.org/initiative/06-seedqual-delivering-genetic-gains-in-farmers-fields/
SODO	Soil Doctors	https://www.fao.org/global-soil-partnership/soil-doctors-programme/about-the-programme/en/
SOWADES	Kenya: Solar water desalination system	https://www.atmosfair.de/en/climate-protection-projects/solar-energy/kenia-solar-powered-water-treatment-plants/
STRASA	Stress-Tolerant Rice for Africa and South Asia	https://strasa.irri.org/home
SWALIM	Somalia Water and Land Information Management	https://www.faoswalim.org/
TRAFLISEN	A traffic light soil water sensor for resource poor farmers	https://aifsc.aciar.gov.au/projects/traffic-light-soil-water-sensor-resource-poor-farmers.html
TSI	Transforming smallholder irrigation into profitable and self-sustaining systems in southern Africa	https://www.aciar.gov.au/project/lwr-2016-137
UBENEFIT	Utilisation of wastewater for fuel and fodder production and environmental and social benefits in semi-arid peri-urban zones of sub-Saharan Africa	https://cordis.europa.eu/project/id/ICA4-CT-2002-10017
WATERMAN	Dissemination of research results in semi-arid and arid ecosystems with a focus on sustainable water resource management in Ethiopia	https://cordis.europa.eu/project/id/31694

Appendix B Data analysis

B.1 Codebook for the interview analysis

Code	Code Group 1	Code Group 2	Code Group 3	Code Group 4	Code Group 5	Code Group 6
Adaptation	Solution					
Cause						Cause
Challenge		State of art				
Cultural impact			Impact			
Economic impact			Impact			
Environmental impact			Impact			
Ethiopia				Focus country		
Hotspot					Location	
Innovation	Solution					
Kenya				Focus country		
livestock						
Mozambique				Focus country		
Policy	Solution					
Primary salinisation						Cause
Recommendation	Solution					
Scientific Knowledge		State of art				
Secondary salinisation						Cause
Senegal				Focus country		
Social impact			Impact			
Technology	Solution					
The Gambia				Focus country		

B.2 Overview of actor constellations by governance function

Actors	Function: Standards and commitments	Function: Information and networking	Function: Financing	Function: Operational
Public actors	0	7	0	7
Private actors	0	0	0	0
Civil society	0	0	0	1
Public + Private	0	9	1	0
Public + Civil Society	0	2	0	3
Private + Civil Society	0	1	0	1
Public + Private + Civil Society	0	2	0	3
Total	**0**	**21**	**1**	**15**

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