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Salinity impacts on agriculture in Sub-Saharan Africa – state of the art and call for action

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Introduction

The research community increasingly warns of escalating biophysical and socio-economic impacts of climate change, with Sub-Saharan Africa (SSA) expected to suffer disproportionately due to rising temperatures, insufficient rainfall and the vulnerability of the population (UNCCC, 2022). Here, climate change results in reduced crop productivity, land degradation, and thereby negatively affects food security and livelihoods (Bain et al., 2013). One pressing land degradation challenge, pervasive throughout SSA and exacerbated by climate change, is soil and groundwater salinisation, which refers to the process of excessive salt accumulation in soil or water (Wang et al., 2023). Salt-affected soils are classified according to their electrical conductivity (EC), their exchangeable sodium percentage (ESP) as well as their pH, and comprise saline (high loads of water-soluble salts) and sodic (high levels of sodium on exchange sites, often high pH), as well as saline-sodic soils (combination of both characteristics) (Richards, 1954). Reported data on the extent and impacts of salinity in SSA, which is necessary for the implementation of effective mitigation and adaptation strategies, remains fragmentary. With the present conference contribution, we provide a synthesis of own recent research efforts which aimed at systematising the available information through desk research and expert consultation, thus identifying knowledge gaps and action needs (Smaoui et al., 2024; FAO, 2024). We specifically focus on: (i) overall scientific knowledge, salinity classification, and geographic extent of salt-affected soils (ii) economic, environmental, social and cultural impacts of salinity, and (iii) the governance of salinity through policies and international initiatives. Further, (iv) the case study of salinity impacts on rice production systems in Eastern Africa (EA) is presented as an illustrative example, highlighting the prospects and challenges for supra-national efforts towards a conclusive understanding and management of the salinity problem in SSA. Based on this, we derive key recommendations for future research and policy efforts.

Methodology

The present conference contribution constitutes a synthesis of the outputs of several recent research efforts, building on various methodological approaches, including desk research, key informant questionnaires, expert interviews, and field visits, amongst others: (I) Smaoui et al. (2024) focussed on 12 countries in SSA, reviewing the available scientific literature on salinity along with topical policy documents. This was complemented by semi-structured interviews with nine experts and extension officers from Ethiopia, Kenya, Mozambique, Senegal, and The Gambia, and an assessment of a database of 30 international cooperative initiatives (ICIs) on salinity and saline agriculture. To examine the ICIs' potential in mitigating and/or adapting to salinity impacts, the following parameters were mapped: geographical focus, funding and accountability mechanisms, main activities, actors involved, and thematic focus. (II) FAO (2024) relied on key informant questionnaires which had been distributed globally via the International Network of Salt-affected Soils (INSAS), aiming at compiling country-specific salinity expertise. For the SSA region, a total of 27 experts representing 17 countries contributed information. The questionnaire, amongst others, tapped into data on mapped extend of salt-affected soils, classification systems, standard methods for salinity parameter assessment, and agronomic salinity management. Preceding efforts of INSAS included the development of the Global Map of Salt-affected Soils (GSASmap) compiling and harmonizing input data from 257.419 soil data points over 118 countries (FAO 2021, Omuto et al. 2023). (III) The case study of salinity impacts on rice production systems in Eastern Africa is the outcome of ongoing networking activities and information systematization conducted under the Eastern & Southern African Saline Agriculture Network initiative (Weltweit e.V.). The presented insights are based on topical literature research and personal communication with experts from Kenya, Tanzania, Mozambique and Rwanda.

Results and Discussion

(i) Overall scientific knowledge, salinity classification, and geographic extent of salt-affected soils. Smaoui et al. (2024), providing 12 systematic country profiles, revealed an uneven coverage of scientific knowledge on salinity across SSA. While countries such as Senegal, Burkina Faso, Kenya, and Ethiopia are relatively well studied, more centrally located countries such as Mali and Chad lack thorough analysis. Further, we identified a bias towards the investigation of coastal salt-affected systems, in contrast to salinity in (semi-)arid inland environments. Previously published estimates of the extent of salt-affected soils in SSA vary widely, indicating inconsistencies in terms of reference data, mapping and salinity classification methods. Reported values range from 19.09 Mha (Tully et al., 2015; refers to saline soils only, including alkaline [sodic] soils the value increases to 71.15 Mha) to 161 Mha (Wicke et al., 2011). FAO (2024) revealed that conventions for classification of salt-affected soils, including laboratory methods for determination of reference salinity parameters and respective threshold values (e.g., electrical conductivity [EC], exchangeable sodium percentage [ESP], etc.) are quite variable between SSA countries. INSAS attempted to overcome these methodological shortcomings by establishing the GSASmap as a data base building on harmonized crowdsourced data inputs. The current version of the GSASmap suggests that 57.2 Mha of topsoil and 67.9 Mha of subsoil in SSA are salt-affected (FAO 2021). A refinement of the GSASmap through continuous provision of harmonized input data, might provide a realistic reference for future topical decision making in SSA (Omuto et al., 2023, 2024).

(ii) Impacts of salinity. Agriculture is a key sector for economic growth and development in African countries (Diao et al., 2010). Therefore, it is crucial to understand not only the environmental, but also the economic, social and cultural impacts of salinisation when developing effective policies aiming at mitigation and adaptation. Through the lens of these four impact categories Smaoui et al. (2024) assessed the trends for the five exemplary countries covered by the expert interviews: (a) **Economic impacts.** Agriculture is the sector most affected by salinisation, with declining yields, loss of productive land and reduced agricultural exports, threatening food security. The economic impact of salinisation extends from local communities to the national level, affecting farmers' incomes and increasing the costs of management and infrastructure. (b) **Environmental impacts.** Salinisation severely reduces water quality, exacerbating water scarcity and damaging freshwater ecosystems. It also threatens the survival of various plant and fish species, leading to a decline in biodiversity. (c) **Social impacts.** Salinisation threatens the livelihoods of many smallholder farmers in Africa by reducing income, contributing to increasing poverty. It also leads to health problems, such as dental disease, caused by the consumption of water from salinized freshwater aquifers. (d) **Cultural impacts.** Changes in traditional agricultural practices and livelihoods are required, as smallholder farmers may be forced to abandon farming due to depleted arable land. This shift can lead to social tensions and conflicts, especially as food security, population growth and poverty pressures intensify.

(iii) Governance of salinity through policies and international initiatives. Smaoui et al. (2024) analysed salinity related policies in the context of soil, water, biodiversity and land degradation from the 12 focus countries. This assessment revealed a lack of national regulations directly addressing salinisation. Nevertheless, salinisation is often mentioned in reports under international biodiversity or desertification conventions. The assessment of ICIs yielded the following insights. The highest percentage of ICIs are located in Mozambique (43.3%), Senegal (30%) and Kenya (26.7%), while Somalia (3.3%), South Sudan (3.3%) and Chad (6.7%) have the fewest. The secretariats of most ICIs are situated in countries classified as part of the 'global north', which highlights a significant North-South imbalance of the ICIs management. This raises concerns about potential imbalances in the management and dissemination of knowledge. Notably, the Netherlands has a dominant presence, hosting the majority of ICIs' secretariats (24.1%). Most ICIs lack transparency in their funding and monitoring practices, which impedes a comprehensive assessment. While some ICIs have set quantitative targets (30%), few have established monitoring frameworks (6.7%), raising concerns about the efficacy of their strategies and the reliability of their project evaluations. The activities of ICIs are primarily concerned with operational matters (83.3%), including research and the development of pilot projects, followed by sharing information and networking (73.3%).

Only 3.3% of the ICIs provide finance, and none exclusively sets standards in the field. Further, there is a bias towards public (30.4%) and public-private ICIs (34.8%), while ICIs exclusively composed of private actors are fully absent. The ICIs demonstrate a greater focus on adaptation to salinisation (25.3%) than on mitigation (9.6%). Moreover, soil and water management represent two of the most prominent themes, with 24.1% and 19.3% of ICIs, respectively, addressing these issues. Other ICIs focus on the cultivation of conventional, salt-tolerant crops (18.1%), while the promotion of the production of halophytes is less prevalent (2.4%). Aquaculture is equally underrepresented (1.2%), even though the interviews indicated that there may be scope for adapting shrimp and fish aquaculture to cope with salinisation.

(iv) Case Study: Salinity in Lowland Rice Production Systems in Eastern Africa (EA). Rice is a staple food crop across Africa, with a growing importance. Currently, rice is grown in 40 African countries on nearly 10 Mha of land, out of which approximately 60% are occupied by lowland rice (Zenna et al., 2017). In continental EA (Tanzania, Uganda, Kenya, Mozambique, Malawi, Burundi and Rwanda), the total rice cropped area amounts to approx. 1.74 Mha (FAOSTAT, status as of 2022). On a global scale, climate change and human mismanagement drive land degradation processes in lowland rice systems, with soil salinity and sodicity becoming increasingly relevant production constraints (Fahad et al., 2019). Salt-affected lowland rice production areas are found across Eastern Africa. They comprise coastal (e.g. the delta areas of major river systems like the Tana, Rufiji, Zambezi and Limpopo) and inland environments (principally along the Eastern Rift Valley). Accordingly, salinity constraints are principally associated with the mangrove and irrigated rice production ecologies (Zenna et al., 2017). Varying salinity types (saline, sodic, saline-sodic) are encountered, depending on the respective biophysical predispositions (Mungai 2004; Omar et al., 2023; Ruganzu et al., 2015; Menete et al., 2008). Country-wide estimated percentage shares of rice produced on salt-affected soils reach 6% in Tanzania and 16% in Mozambique (Van Oort 2018). According to FAO (2024), rice is the most prominent crop cultivated on salt-affected soils in SSA. This may be ascribed to the fact that under flooded lowland conditions, effective salinity impact can be mitigated to a certain extend via dilution and/or leaching of salts (Samy et al., 2024). Nonetheless, it has been established that salinity and sodicity constitute significant yield reducing factors in the region (Omar et al., 2023; Ruganzu et al., 2015), even though conclusive statistics on salinity-induced yield gaps/production losses are not available. The International Rice Research Institute (IRRI), in collaboration with the respective National Agricultural Research Systems (NARS) of Kenya, Tanzania and Mozambique, is intensifying its efforts in developing salinity tolerant rice cultivars adapted to the local context by means of tolerance screening and breeding, with a few varieties having been released in recent years, which, however, exhibit rather poor adoption rates (Mheni et al., 2024; Samy et al., 2024; Omar et al., 2023). At the same time, local Research and Development (R&D) so far is missing an opportunity in effectively promoting agronomic salinity management strategies, e.g. improved water management, application of (organic) soil amendments and manures, green manures and phytoremediation, which are well established practices in Asian salt-affected rice systems (Omar et al., 2023).

Recommendations and Future Perspectives

Based on the above, we derive the following recommendations for future research and policy efforts in SSA:

- Increase research efforts on salinity and thus close data and knowledge gaps in the region, especially with regard to inland/dryland environments.
- Align data collection and laboratory analyses protocols across the region for better comparability, e.g. via the country-driven harmonization efforts of INSAS.
- Improve knowledge exchange and cooperation among stakeholders across countries.
- Support effective initiatives and provide funding opportunities.
- Improve policy support through awareness raising amongst decision makers.

With regard to rice production on salt-affected soils in EA, we see the following opportunities:

- Close knowledge gaps on quantification/characterisation of salt-affected rice production systems, i.e. exact area affected, extend of specific salinity types, salinity-induced yield gaps/production losses.
- Maintain transnational efforts to develop and promote salinity tolerant rice cultivars adapted to the local context, considering the factor of salinity type diversity and complementary trait requirements concerning agronomy and consumer preferences, aiming at wider adoption among farmers.
- Develop local R&D capacities with regard to agronomic salinity management strategies (Saline Agriculture) adapted to lowland rice systems.

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