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Farmers' and academia's views"

Participatory research for agronomic salinity management – experiences from coastal peri-urban vegetable production in Maputo, Mozambique

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Abstract

Salinisation of agricultural soil resources is an ever increasing problem for global sustainable food production. Often, it results from interplay of climate change impacts and human agronomic mismanagement. The concept of Saline Agriculture (SA) provides a versatile toolbox of agricultural practices which have the potential to sustain agricultural production under saline conditions and partly even reverse salinisation through soil remediation processes. SA combines diverse soil, water and crop management approaches which intend to improve soil health parameters, in order to minimise salinity levels within the crops' root zone and/or mitigate salinity stress for the plants. However, SA practices are not universally applicable. They need to be tested locally and adapted to the particularities of production systems. Especially smallholder vegetable production systems in (sub-)tropical environments are still rather poorly understood in this regard. Addressing this knowledge gap, an ongoing project initiative is implementing a participatory pilot of SA practices in Maputo's peri-urban coastal vegetable production zones, in southern Mozambique. A consortium of research institutions, farmer associations, agricultural extension bodies and non-governmental organisations conducted an exploratory study to understand the local extent, farmers' perception, and agronomic implications of salinisation in the target region. A mixed method approach was applied, building on stakeholder interviews, field observations, and a participatory soil and water survey. Currently, the project evaluates the local adaptability of selected SA practices in participatory field trials. Preliminary results confirm (a) the pertinence of salinisation as a local driver of land degradation, with salinity levels significantly surpassing threshold levels recommended for vegetable production, (b) a considerable but expandable (tacit) knowledge level on salinity management by the local farming community, and (c) the potential of innovative SA practices to be sustainably introduced into the local production system. The latter include different organic manures, selection of tolerant cultivars, improved fallows with salt tolerant green manures like Sesbania spp. and salinity monitoring with portable soil and water sensors. The presented poster shares these technical insights along with reflections on the participatory methodology of the project, in order to provide impulses for further applied research initiatives on SA.

Keywords: Farmer field school, farmers' perception, land degradation, local knowledge, saline agriculture, socio-ecological niche, soil salinity

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Introduction

- Saline Agriculture (SA) provides a versatile toolbox of agronomic practices which have the potential to sustain agricultural production under saline conditions.
- Practicable soil and water assessment tools must be accessible to farmers in order to correctly categorize and monitor the specific salinity level.
- The successful management of salinity is highly context specific, which makes multidisciplinary and participatory SA technology development relevant.
- Maputo's peri-urban coastal vegetable production zones in southern Mozambique provide an interesting case study (Figure 1), given that SA approaches for smallholder vegetable production systems in (sub-) tropical environments are poorly developed.
- An exploratory study was conducted to understand the local extent, farmers' perception, and agronomic implications of salinization in the target region, followed by participatory field trials for SA piloting.

Figure 1: Typical aspects of salinity in Maputo's coastal vegetable production zones: Unproductive plots due to high soil salinity (a) High (saline) groundwater tables (b); Soil crusting (c); Leaf yellowing on collard green crop (d).

Methodology

1) Stakeholder interviews and field observations were conducted between April and July 2018, followed by qualitative analysis, in order to map out local perception and management of soil salinity.
2) A participatory mapping workshop with farmer representatives was conducted in July 2018 to define the perceived spatial dimensions of salinity. Systematic soil and water sampling/analysis followed, with the objective to compare farmers' categorization with standard salinity parameters (EC_e, EC_w). Since November 2020, portable soil and water sensor equipment is being piloted and calibrated against standard salinity parameters.
3) A participatory field trial is being conducted throughout the cropping seasons of 2021 and 2022, comparing different SA strategies. A randomized complete block design is applied on farmer plots with different salinity levels. Farmer Field Schools are aligned with the trial.

Results and Insights

1) Local Salinity Knowledge

- A variety of sensory salinity indicators are used by farmers (plant symptoms, salt crusts, tasting, indicator plants; Figure 1 c, d).
- Spatial and temporal dynamics of the salinity problem are acknowledged/explained by farmers.
- Farmers apply a variety of agronomic strategies to mitigate the negative effects of salinity. Most commonly practiced are increased chicken manure applications and use of tolerant crop species.
- Nonetheless, knowledge gaps and potential entry points for innovative SA approaches were identified.

2) Salinity Evaluation and Monitoring

- Local farmers' spatial salinity categorizations compared well with standard soil and water measurements, especially at higher salinity levels (Figure 2). Local salinity assessment thus can serve as a tentative proxy-indicator for salinity levels.
- However, standard salinity assessment should complementarily inform salinity management decision making.
- Portable soil and water sensor equipment provides a cost-effective tool for improving salinity related agricultural extension services (Figure 3 f).

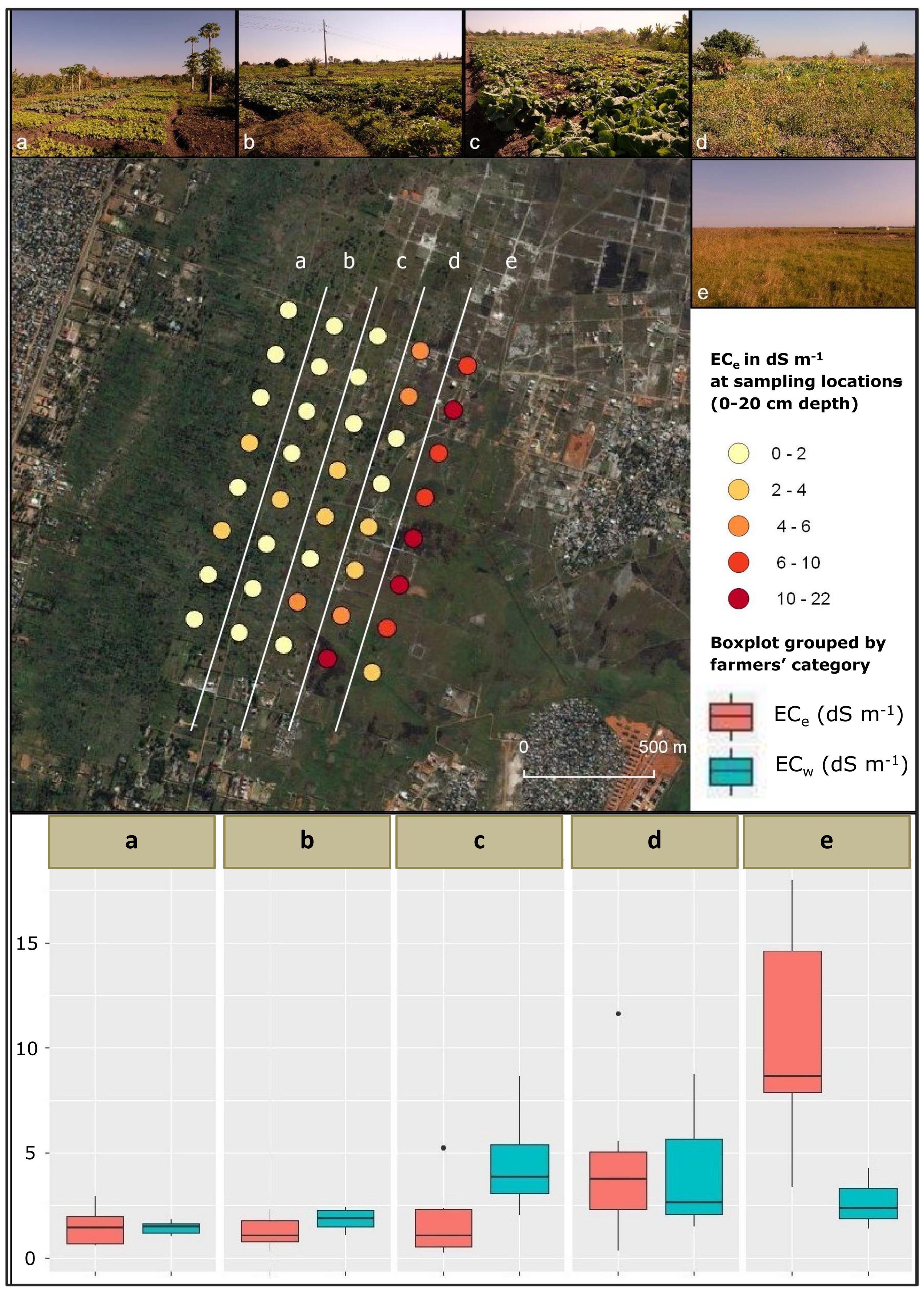

Figure 2: Measured salinity levels of upper 20 cm soil layer (EC_e) and irrigation water source (EC_w) plotted against local farmers' salinity categorization (a-e), which were described as: (a) 'non-saline', (b) 'slightly saline' (25-50% yield loss), (c) 'saline' (50-75% yield loss), (d) 'too saline for crop production' (75-100% yield loss), (e) 'highly saline'. Upper section: Photographs of each category, demonstrating apparent changes in crop health and land use. Middle section: Spatial representation of EC_e for individual sample points. Lower section: Boxplot representation of EC_e and EC_w grouped by farmers' salinity categorization. ANOVA and Fisher's LSD test confirmed farmer categories c, d and e as statistically distinctive entities based on either EC_e or EC_w measurements; while a differentiation between categories a and b couldn't be substantiated.

3) Saline Agriculture Field Trials

- Innovative SA practices with potential to be sustainably introduced into the local production system were identified and are successively tested, a.o.: * animal manures * biofertilizer * biochar * composts * slow-release urea * tolerant cultivars * *Sesbania* spp. green manures * (Figure 3 a, e).
- Farmer Field School format proved to be a viable participatory approach. Farmers strongly informed trial design and support monitoring (Figure 3 c, d).
- The participatory trial setup proved to partly compromise scientific accuracy but to increase ownership of local stakeholders.

Figure 3: Impressions of participatory trial setup and monitoring: Application of biochar amendment (a), Data collection at lettuce harvest (b), Farmer Field School session (c), Preparation of experimental plots (d), *Sesbania sesban* pilot demonstration (e), Monitoring of soil parameters with portable sensor equipment STEP Systems COMBI 5000 (f).

Conclusions and Outlook

- Globally, more application-oriented research is needed to further the understanding of sustainable salinity management adapted to the particularities of smallholder vegetable production systems in the Global South.
- Smallholder farmers exposed to salt-affected soil and water resources often demonstrated a considerable but expandable (tacit) knowledge level on agronomic salinity management.
- Local sensory approaches for salinity assessment should be complemented by cost-effective portable soil and water sensor equipment for improved salinity management decision making.

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Introduction

Salinisation of agricultural soil resources is an ever-increasing problem for global sustainable food production. The concept of Saline Agriculture (SA) provides a versatile toolbox of agricultural practices which have the potential to sustain agricultural production under saline conditions and partly even reverse salinisation through soil remediation processes. SA combines diverse soil, water and crop management approaches which intend to improve soil health parameters, in order to minimise salinity levels within the crops' root zone and/or mitigate salinity stress for the plants. Equally important is the access to practicable soil and water assessment tools in order to guarantee a correct categorization and monitoring of the specific salinity level (FAO 2022). The successful management of salinity is highly context specific and needs to consider local agro-ecological and socio-economic particularities. This makes multidisciplinary and participatory SA technology development relevant. Maputo's peri-urban coastal vegetable production zones in southern Mozambique provide an interesting case study, given that SA approaches for smallholder vegetable production systems in (sub-)tropical environments are poorly developed (Herrmann 2019). Addressing this knowledge gap, we – a consortium of research institutions, agricultural extension bodies and non-governmental organisations – are implementing an applied research project on salinity management in collaboration with vegetable farmer associations of Maputo. Within this publication we share preliminary technical insights along with reflections on the participatory methodology of the project, in order to provide impulses for further research and development initiatives on SA.

Material and Methods

The project's activities are implemented in the vegetable production area of the district of KaMavota, one of Maputo's so called *Green Zones*, located on a vast coastal plain. Here, over 8.000 vegetable producers farm on more than 900 ha agricultural land (Schmidt 2017). Leafy vegetables constitute the predominant crop group (Smart et al. 2016). Maputo lies within a tropical savannah climate, being characterized by a clear seasonality (warm/wet-season between November-March, cool/dry-season between April-October) and an average annual rainfall of 800 mm (Bacci 2014). Dark clayey wetland soils (Calcaric/Eutric Fluvisols, Gelyic Solonetzes) are predominant. Soil salinity and sodicity are historic problems in the project region, based on the occurrence of saline sediments and progressing seawater intrusion (Eschweiler 1986, Matsinhe et al. 2008). These phenomena manifest themselves in the form of visible soil degradation as well as compromised crop production (Herrmann 2019). The project follows a sequential mixed-methods approach, organized in three working packages:

(1) Appraisal of Local Salinity Knowledge: Between April and July 2018 we conducted stakeholder interviews (farmers, extension workers, technical experts from local government, science and NGOs) and field observations, following a purposive sampling approach (N = 31). The collected data was analysed qualitatively (deductive and inductive coding), in order to map out local perception and management of soil salinity.

(2) Approaches to Salinity Evaluation and Monitoring: We conducted a participatory mapping workshop with farmer representatives in July 2018. Participants were asked to define zones of differing soil salinity level and to draw them on transparencies overlaid on an aerial photograph of the study area. In order to compare farmers' categorization with standard salinity parameters we conducted a systematic grid-based sampling (200 x 200 m on 135 ha) of composite soil samples (0-20 cm soil layer) and simple samples from adjacent irrigation water sources. Since November 2020, we piloted portable soil and water sensor equipment (STEP Systems COMBI 5000, HANNA Instruments HI993310 / HI98192), and calibrated it against standard salinity parameters. Laboratory analyses were conducted at the soil and water laboratory of the University Eduardo Mondlane (UEM), Maputo (Wijnhoud 1997). Spatial analysis and visualization of the data was realized with QGIS Version 2.18.11 (QGIS Development Team, 2016). All statistical tests and data visualizations were performed using the RStudio environment (version 4.1.1, R Core Team 2021).

(3) Field Trials of Saline Agriculture Approaches: Following the socio-ecological niche concept (Ojiem et al. 2006), we identified promising SA practices from literature for further assessment. We conducted successive participatory field trials throughout the cropping seasons of 2021 and 2022, comparing different soil improvement strategies, including local conventional (different combinations of chicken manure, NPK and urea applications) and innovative SA approaches (plant-based composts, manure-based biofertilizers, biochar). Collard greens (*Brassica oleracea* var. *costata* 'Tronchuda') and lettuce (*Lactuca sativa* 'Great Lakes') constituted the research crops. We applied a randomized complete block design. The trial plots are located at three farmer fields with different salinity/sodicity levels (Table 1). We monitored key soil, water and crop parameters during crop growth, along with yield parameters at harvest. Laboratory analyses were conducted at UEM (Wijnhoud 1997). Regular Farmer Field School sessions were aligned with the trial.

Table 1: Initial soil texture and salinity/sodicity characterization of the trial's experimental sites at 0-20 cm soil layer; where $EC_{1:2.5}$ = electrical conductivity in 1:2.5 soil water suspension, EC_e = electrical conductivity of the saturated soil paste extract (calculated from $EC_{1:2.5}$ based on soil texture class, according to Wijnhoud 1997), ESP = exchangeable sodium percentage, and $pH_{1:2.5}$ = pH in 1:2.5 soil water suspension.

Site	Soil Texture	$EC_{1:2.5}$	EC_e	ESP	$pH_{1:2.5}$
1	sandy loam	0.53	2.39	4.57	8.9
2	sand clay loam	1.21	3.02	20.75	9.0
3	sandy loam	0.72	3.24	30.03	9.6

Results and Discussion

(1) Appraisal of Local Salinity Knowledge: Our stakeholder interviews and field observations revealed that farmers use a variety of sensory indicators of salinity, including primarily plant symptoms, salt crusts, tasting of soil and water, and indicator plants. Furthermore, farmers acknowledge and comprehensively explain the complex dynamics of salinity along spatial and temporal gradients, e.g. seasonal fluctuations in salinity levels, or the gradual multi-annual salinization processes along deficient drainage channels. In order to cope with the experienced constraints, local farmers have developed a variety of agronomic strategies, understood to

mitigate the negative effects of salinity. Most commonly practiced are increased chicken manure applications, the incorporation of plant organic matter, and the use of tolerant crop species such as beetroot (*Beta vulgaris* subsp. *rapacea* var. *conditiva)*. The findings of the present research compare well with other reported case studies on salt-affected smallholder agricultural production systems from around the world, which equally highlight the predominance of tacit salinity knowledge, the importance of sensory salinity indicators, and the existence of locally evolved simple SA techniques (Herrmann 2019). Nonetheless, we identified knowledge gaps and potential entry points for innovative SA approaches. The latter include animal manures, plant-based composts, biochar, manure-based liquid biofertilizer formulations, slow-release urea, tolerant crop species/cultivars, and green manuring with *Sesbania* spp.

(2) Approaches to Salinity Evaluation and Monitoring: Within the participatory mapping workshop, farmers defined five soil salinity categories. They are based on the perceived severity of soil salinity and the respective impacts on crop production: (a) 'non-saline', (b) 'slightly saline' (25-50% yield loss), (c) 'saline' (50-75% yield loss), (d) 'too saline for crop production' (75-100% yield loss), (e) 'highly saline'. Spatially they have been described as distinctive consecutive strips following a NW-SE orientation within the study area. Local farmers' spatial salinity categorizations compared well with standard soil and water measurements, especially at higher salinity levels. On a global scale, measured EC_e (0-20 cm) values ranged from 0.23 to 17.99 dS m^{-1}, with a mean of 3.82 dS m^{-1}. EC_w values varied between 1.01 to 8.75 dS m^{-1}, with a mean of 2.58 dS m^{-1}. ANOVA and Fisher's LSD test confirmed farmer categories c, d and e as statistically distinctive entities based on either EC_e or EC_w measurements; while a differentiation between categories a and b couldn't be substantiated (Herrmann 2019). Local salinity assessment thus proved effective as a tentative proxy-indicator for salinity levels. Nonetheless, scientific-based salinity assessment should complementarily inform salinity management decision making, in order to improve accuracy. Portable soil and water sensor equipment provides a cost-effective tool for this requirement. However, in some cases, locality-specific correlations between the respective equipment-provided (e.g. AM) and standard salinity parameters (EC) are required (Shahid 2013).

(3) Field Trials of Saline Agriculture Approaches: Conclusive data analysis of the project's field trials is still pending, and thus are locally proven SA management recommendations. In terms of methodology, situating the scientific field trial in farmers' plots and aligning them with Farmer Field Schools proved to be a viable participatory approach. Farmers strongly informed initial trial design and supported monitoring. Especially the Farmer Field School sessions provided an active platform for continuous experience exchange and feedback loups between all stakeholders, and thus increased farmers' ownership. However, the participatory trial setup partly compromised scientific accuracy, due to challenges especially in guaranteeing synchronized management between trial plots, and preventing external disruptive factors such as theft of crops etc. These shortcomings are a general phenomenon in participatory on-farm research, and are specifically relevant for the investigation of biophysical responses. They might be addressed by a more restrictive/researcher-centred trial design (Franzel and Coe 2002).

Conclusions and Outlook

In the face of global climate change and increasing human natural resource use, the sustainable and context-specific management of soil salinity in agricultural systems becomes ever more relevant. The present study presents preliminary findings of a SA pilot project in a smallholder vegetable production system in southern Mozambique, providing reference points for ongoing and future initiatives in similar contexts. It has been demonstrated that (i) farmers have a considerable (tacit) knowledge level on salinity management, which can guide local SA research and development, (ii) local farmers' salinity assessment, complemented with portable sensor equipment can meaningfully inform agricultural extension advice and land-use decision making in a cost-effective manner, and (iii) innovative SA practices have the potential to be sustainably introduced into the local production system. Field trials and demonstrations which test/showcase the latter, require a conductive environment, which equally allows for stakeholder participation and (scientific) comparability between experimental units. We intent to further advance SA research in southern Mozambique, applying refined trial designs.

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