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Project Report 7

STRATIGIES FOR SCALING UP RECOMMENDED TECHNOLOGIES IN ETHIOPIA AND SOUTH SUDAN





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REHABILITATION AND MANAGEMENT OF SALT-AFFECTED SOILS TO IMPROVE AGRICULTURAL PRODUCTIVITY (RAMSAP) IN ETHIOPIA AND SOUTH SUDAN

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ACRONYMS

A/TVET	Agricultural Technical and Vocation Education and Training
AGP	Agricultural Growth Program
BoA	Bureau of Agriculture
CASCAPE	Capacity Building for Scaling up of Evidence-Based Best Practices for Increasing Agricultural Production in Ethiopia
CDSF	Capacity Development Support Facility
CISEAU	Centre Virtuel de l'eau agricole et ses usages
CSA	Central Statistical Agency
DAs	Development Agents
EARO	Ethiopian Agricultural Research Organization
ECe	Electrical Conductivity of the soil saturation paste extract
EIAR	Ethiopian Institute of Agricultural Research
EPRDF	Ethiopian People's Revolutionary Democratic Front
ESP	Exchangeable Sodium Percentage
ETo	Reference Evapotranspiration
FFS	Farmers Field Schools
FREGs	Farmer Research and Extension Groups
FTC	Farmer Training Centre
GTP	Growth and Transformation plan
HPP	High Potential Perennial
ICBA	International Center for Biosaline Agriculture
ILRI	International Livestock Research Institute
IPTRID	International programme for Technology and Research in Irrigation and Drainage
LGP	Length of Growing Period
LLRP	Lowland Livelihood Resilience Project
LPC	Low Potential Cereal
MoA	Ministry of Agriculture
MoP	Ministry of Peace
MoSF	Ministry of State Farms
MoWIE	Ministry of Water Irrigation and Energy
PED	Pre-Extension Demonstration
PRA	Participatory Rapid Assessment
RAMSAP	Rehabilitation and Management of Salt-Affected Soils to Improve Agricultural Productivity in Ethiopia
RARIs	Regional Research Institutes
RC	Research Centres
SAR	Sodium Adsoprtion Ratio
SMSs	Subject Matter Specialists
TDS	Total Dissolved Salts
TOT	Training of Trainers

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EXECUTIVE SUMMARY

Soil salinity and poor water management problems threaten the food security of smallholder farmers in Ethiopia and South Sudan. Technologies and practices are well-known and readily available for reclamation of saline/sodic soils and to improve water management at the farm level. These include (1) good on-farm soil management practices (minimum tillage and mulching to avoid compaction, proper seedbed preparation, and land leveling, etc.); (2) hydraulic measures such as use of good quality irrigation water and efficient irrigation methods (based on ETo crop requirement, avoid flooding/ basin method) and adopting appropriate drainage systems; and (3) implementing biosaline agriculture which involves the use of salt-tolerant and drought-tolerant crop and forage species. It is saddening to note that there is little or no institutionalized research, extension, and development strategies to alleviate these problems despite these threats. There are no research efforts to generate data/information on the extent of the problem, causes, and possible remedial measures.

The biosaline approach is most appropriate under the Ethiopian conditions because it allows effective and economically practical use of salt-affected lands for growing food and fodder crops that are most needed in the country. Some fodder species such as sesbania serve as bio-drainage plants and are effective in lowering the groundwater table (via bio-pumping) for areas where high salinity and canal seepage have become problematic. The ICBA-RAMSAP project introduced more than 20 genotypes of different food (barley, quinoa, sorghum), forage (Rhodes grass, buffel grass, Panicum, etc.), forage legumes (alfalfa), and shrubs/trees (sesbania) that are suitable for salt-affected lands. What remains to be done is to activate the extension services for scaling up these technologies to more expansive areas where salt-affected soils are prevalent.

This study documents the scalable experiences and provides steps and guidelines in scaling up and wide-scale implementation of the biosaline agricultural practices piloted by the ICBA-RAMSAP project. In addition, the report captures current strategies, gaps, and challenges along with suggested solutions and recommendations, and opportunities to scale up and wide-scale adoption of best practices to improve crop productivity and mitigate the spread of soil salinity. These may include technological, socio-economical, and institutional aspects such as input supply, market linkage, access to credit. Many opportunities could harness scaling up efforts, such as extension advisors at the local level and lowland research stations nearby, the growing demand for high-value agricultural products from the ever-increasing middle-class population, and the increase of innovative farming communities.

Some of the recommendations for mitigating the challenges/gaps and harnessing the opportunities include restricting the use of saline water for irrigation, improving the water use efficiency in agriculture, adopting improved on-farm soil management practices, such as minimum tillage mulching to avoid compaction. Furthermore, proper seedbed preparation, land leveling, and organic matter management enhance soil fertility by adding compost, farm yard manure, crop residue, are recommended. Capacity building through training and producing qualified irrigation agronomists from agricultural universities is essential. Particular attention should be given to the production and distribution of high-quality seeds of potential crops. Creating awareness among policy makers and farming communities is central to overcoming these challenges. Create increased inter-institutional collaboration in irrigation water and saline soil management. Improved communication and coordination to establish a solid inter-institutional collaboration mechanism between different organizations is paramount for saline soil irrigation management to improve agricultural productivity.

01

INTRODUCTION

1.1 Background

Increasing salinity remains a challenge to sustainability of irrigated agriculture in Ethiopia and South Sudan as it reduces natural biodiversity as well as farm and livestock productivity. Agriculture sector in Ethiopia supports 85% of the work force. About 85% of the population living in rural areas is directly dependent on agriculture for their livelihood. There are seven million smallholder farmers, which produces more than 95% of the total agricultural outputs including food crops, cereals, oil seed and pulses. Cotton and sugar are mainly produced on state-owned large-scale enterprises. Ethiopia also has large livestock resources including cattle, sheep, goats and camels. Despite this high biodiversity and distinctive ecosystems, Ethiopia is one of the poorest countries of the world and widely known as a country of famine. Food shortages are widespread and since 1970 there have been severe famines almost once per decade.

Land degradation is considered one of the major causes of low and in many places declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia. Today, Ethiopia stands first in Africa in the extent of area of salt-affected soils due to human-induced and natural causes. Currently, the area under salt-affected soils covers about 5% of the total agricultural area (MoA, 2017). The problem is most prevalent in the Rift valley region (lower and upper Awash basin), where irrigated commercial farming of cotton and sugarcane has been practiced for many decades. Approximately 11 million hectares of land (Mha) (i.e., 9% of the country's total landmass and 13% of the irrigated area) are salinized, out of which 8 Mha have combined salinity and alkalinity problems whereas the rest 3 Mha have alkalinity problems. About 9% of the population lives in the areas affected by salinity. The growing occurrence of salt-affected soils is affecting the productivity of irrigated lands and farm and livestock productivity. This problem directly or indirectly affects the livelihood of poor rural communities and the national economy. To meet food security challenges, transforming salt-affected soils into productive lands and preventing the spread of salinity in other areas is paramount in Ethiopia.

In South Sudan, agriculture account for 36% of the non-oil GDP with approximately 80% of the population living in rural areas largely dependent on subsistence farming, and 75% of the households consuming cereals as a main part of their daily diet. Despite abundant water supplies, only 5% of total 30 million ha arable land is cultivated. Crop yields are extremely low, which negatively affects incomes and livelihood of poor farmers. Lack of agricultural inputs such as seed and fertilizer, poor advisory services and inefficient irrigation management are considered as the major barriers. Although South Sudan has highest livestock per capita in the world, with 23 million head of cattle, sheep, and goats, there is little use of improved varieties of seed or breeds of livestock. To improve livestock productivity, there is a strong need for improved forage varieties that are resistant to common diseases. The salt-affected lands in South Sudan are in the White Nile irrigation schemes. These areas have hardly been utilized for agricultural production despite having great potential due to freshwater availability from Nile. Therefore bringing back these degraded lands into acceptable production levels is essential to ensure food security and social stability.

There is plenty of relevant case studies in the literature and available knowledge on rehabilitation and management of saline soils at an international scale (Arora et al., 2017; FAO, 1997, 2005; Hussain et al., 2020; Qadir and Oster, 2004; Qureshi et al., 2007). But the existing knowledge needs to be refined and tested for relevance under local climatic, soil, and crop conditions. Testing and disseminating some of these options in rehabilitating salt-affected soils in Ethiopia is a priority issue to achieve food and income security for the farming communities in the semi-arid lowland regions.

Although several reports exist on the causes and extent of salt-affected soils in Ethiopia (Adhanom, 2019; Asfaw et al., 2016; Zewdu et al., 2017), very little or nothing has been done to rehabilitate salt-affected soils. As a result, the poor smallholder farmers and agro-pastoralists, and particularly women, experience severe food insecurity and abject poverty. Cognizant of these problems, the International Center for Biosaline Agriculture (ICBA) initiated an action research project entitled, "Rehabilitation and Management of Salt-Affected Soils to Improve Agricultural Productivity in Ethiopia (RAMSAP). The project was implemented in target regions of Ethiopia and South Sudan.

The project has been exploring best practices to adapt to and mitigate soil salinity/sodicity. Following several exploratory surveys and studies (e.g., baseline socio-economic survey and assessment of the salt-affected soils and irrigation water), the project focused on (1) the characterization and mapping of salinity/sodicity of irrigated lands by collecting soil samples at various depths and assessing irrigation water quality in the target irrigated districts aimed at developing small-scale water management strategies; (2) the adoption of a biosaline approach for the remediation of salt-affected soils, whereby the project introduced and tested production of the salt-tolerant crop, forage grasses and legumes along with trees and shrubs; and (3) the evaluation of farmer constraints and challenges for the adoption of best practices and scaling-up.

1.2 Objectives

The project has generated scalable experiences and lessons that can be disseminated to other areas where soil salinity/sodicity is prevalent. The specific objectives of this report are to:

(1) Document the extent, causes, and current status of salt-affected soils.

(2) Explore existing strategies and plans put in place in the research and extension systems aimed at improved irrigation water management and rehabilitation of salt-affected soils.

(3) Identify gaps, challenges, and opportunities (technical, socio-economic, policy) for broader adoption of technologies and best practices available to rehabilitate salt-affected soils;

(4) Provide recommendations for bridging the identified gaps/challenges in the implementation of strategies; and

(5) Develop scaling guidelines/strategies and incentives for wide-scale adoption of best practices in irrigation and salinity management technologies by farmers in saline salt-affected areas

1.3 Methodology for the assessment

This report is based on an extensive literature review of both grey and published material, which included archival material on the management of salt-affected soils. A comprehensive review of the project documents and other available literature was made on the subject to (1) capture the causes, extent, and current status of salt-affected soils in Ethiopia; (2) document any scalable experiences and management packages to rehabilitate salt-affected soils; and (3) identify and document research, extension and policy strategies/plans put in place, or the lack thereof, for the rehabilitation of salt-affected soils in Ethiopia.

The scientific literature on the topic was searched through the web using search engines such as Google scholar and science direct by using keywords and phrases such as saline soils; salt-affected soils; irrigation water quality. In addition, the hard copies of the locally produced journals and proceedings, such as articles in the Ethiopian Journal of Natural Resources and the proceedings of the annual conferences of the Ethiopian Society of Soil Science, were explored for relevant information. Much of the materials presented and discussed on the historical perspectives and background of soil and water management in the commercially irrigated agriculture systems are extracted from the sources listed in the references section.

02

DEVELOPMENT OF SALT-AFFECTED SOILS

2.1 Defining soil salinity and sodicity

Salt-affected soils refer to the presence of excess soluble salts, sodium ions, or a combination of both. When soils contain a high concentration of water-soluble salts (e.g., CaCl, MgCl, and NaCl), salt-affected soils develop (Ayub et al., 2020). Different classes have been identified for the salt-affected soils (Ayub et al., 2020; Weil and Brady 2016). When exchangeable sodium is present more than Ca and Mg, the salinization process is referred to as sodification, and the soils are termed as sodic or saline-sodic soils.

Salt-affected soils are classified based on the electrical conductivity of the soil saturation paste extract (ECe), a measure of exchangeable salts in the soil; exchangeable sodium percentage (ESP), which identifies the degree to which the exchange complex is saturated with Na, and sodium adsorption ratio (SAR) that provides comparative information on the concentration of sodium and divalent cations (Ca and Mg) in the soil solution, and the soil reaction; and the pH value that identifies the degree of alkalinity of the soil. The dividing line between saline and non-saline soils is established at ECe = 4 dSm-1; ESP = 15, SAR = 13, and pH = 8.5 (Table 1).

Two types of salinization processes are identified – primary salinization and secondary salinization. Primary salinization occurs naturally where the soil parent material is rich in soluble salts, or in the presence of a shallow saline groundwater table, and under the semi-arid to arid climatic conditions, which allow limited leaching of the soluble salts from the soil. Secondary salinization occurs when significant amounts of water are provided by irrigation, with no adequate provision of drainage for the leaching and removal of salts, resulting in the soils becoming salty (Ayub et al., 2020; Furi et al., 2011). Improper soil and water management practices that contribute towards the development of secondary salinization include (1) improper water management such as irrigation with saline water, over-irrigation, or insufficient drainage that raises the groundwater table, potentially causing salinity build-up; (2) poor leveling of fields resulting in differences in elevation and uneven distribution of water resulting in salinity build-up in the patches with low infiltration rate and at lower parts where the ground water table is closer to the surface; (3) use of heavy machinery leading to soil compaction and poor drainage; among others (CISEAU/IPTRID/FAO, 2005)

Soil salinity/sodicity is abiotic stress that severely affects soils' fertility and productivity and hence contributes to food insecurity and poverty in afflicted areas. Soil salinity alters soil physical and chemical properties such as swelling and dispersion of clay colloidal particles due to excess exchangeable Na+, in the case of sodic soils (Farifteh et al., 2006). It also hinders the growth of crops by limiting water and mineral uptake by altering water infiltration, air movement, root penetration, and seedling emergence problems. Plant nutritional disorders may arise from decreased or increased solubility and availability of essential nutrients caused by the excessive accumulations of specific ions such as Na+, HCO3, CO3, SiO3, etc. (Pearson, 2004). Classification of salt-affected soils (Weil and Brady, 2016, CISEAU/IPTRID/-FAO, 2005)

Table 1. Classification of salt-affected soils

Salinity classes	ECe (dSm^{-1})	ESP (%)	SAR	pH
Non-saline (normal)	<4	<15	<13	< 8.5
Saline soil	> 4	< 15	<13	<8.5
Sodic (alkaline) soil	< 4	> 15	>13	>8.5

ECe, Electrical conductivity of the soil saturation paste extract 25oC;
ESP = Na/CEC*100; SAR = [Na] ÷ 0.5 [Ca +Mg] ½

2.2 The extent of salt-affected soils in Ethiopia

In Ethiopia, salinization/sodification is among the most common land degradation processes in the arid and semiarid lowlands. Ethiopia stands first in Africa and seventh in the world in the extent of salt-affected soils, with an estimated 11 million hectares (Mha) being affected by different types of salinity, which corresponds to 9% of the total landmass and 13% of the irrigated areas in the country. Out of the 11 Mha, 8 Mha have combined salinity and sodicity problems, and 3 Mha are dominantly sodic. The consequent yield reductions are estimated to be as high as 50%, causing billions of dollars of annual loss to the national economy. However, more worrying is that an estimated 44 million ha (36% of the total land area) additional is potentially susceptible to soil salinity in Ethiopia (Adhanom, 2019; Qureshi et al., 2018). The problem may worsen with the current surge to expand irrigated wheat production in the lowlands unless appropriate on-farm soil and water management practices are implemented.

In the context of increasing climate change with increased temperature, evaporation rates, and flooding, the situation is expected to exacerbate further (Worku et al., 2019). Rainfall is low and erratic to wash the salt from the root zone, creating conditions for both primary and secondary salinization (G/Selassie, 1993; Qureshi et al., 2018). The loss of vegetation in over-grazed pastoral lands can result in the exposure of soils to a greater risk of salinization (Qureshi et al., 2007).

2.3 Salinity expansion in Ethiopia

The commercial state farms were first established during the 1960s in the middle and lower Awash plains, which have relatively better infrastructures along the main roads to the ports of Asab and Djibouti, thus attracting commercial farming in this area. Historically, when irrigated commercial farms were first started, the soils were almost non-saline, and although the groundwater was saline, the water table was deep enough (>10 m; Abegaz and Tadesse, 1996). Back then, water from the Awash River was classified as moderately safe for irrigation use, having total dissolved salts in the range of 0.32 to 0.6 dS/m (EARO, 1996). Consequently, the Ministry of State Farms (MoSF) has established pilot testing sites at Melkasadi, Dubti, and Amibara to try various hydraulic measures, including leaching and drainage systems (surface or sub-surface).

Reports indicate that the extent of salt-affected soils has increased significantly from 1972 to 2014 due to poor irrigation practices, use of poor quality irrigation water, and lack of drainage systems. Recent estimates indicate that about 80% of Dubti/Tendaho state farms are salt-affected, with 27% saline, 29% saline-sodic, and 24% sodic (Qureshi et al., 2018). The causes for primary salinization are naturally occurring salts originating from the parent materials that are rich in soluble salts. Hence, soils are naturally saline in the subsurface horizon. The natural salts are introduced into the crop root zone through shallow groundwater, natural saline seeps, and marine origin. Saline geologic deposits and saline groundwaters often exist along the flow path (Qadir and Oster, 2004). The development of persistent shallow groundwater, capillary rise due to high evaporation rate, coupled with natural saline seep, have converted about 70% of the irrigated areas (17,000 ha) into wasteland (G/Selassie, 1993).

The leading causes of secondary salinization include low-quality irrigation water, inadequate drainage, leaching facilities, and poor on-farm soil and water management practices, including poor land leveling (Ngeborg, 1986). Water application above crop and leaching requirements has contributed significantly to the groundwater build-up. A rapid assessment by the Amibara irrigation project indicated that a minimum of 60cm depth of excess water was applied annually. Some plots resembled mini pools rather than production fields, thus contributing, on average, to a 40-50 cm increment of groundwater depth (G/Selassie, 1993). As a result, a shallow groundwater table (critical depth = 1.5 m) containing mineralized volcanic rocks enriched with total dissolved salts has become a problem in the middle and lower Awash valley, including Dubti and Amibara areas (Furi et al., 2011).

A previous survey on the nature and type of salinity problem in the Melka Sadi area of the middle Awash indicated that waterlogging is the primary cause for a rising water table and salinity build-up (G/Selassie, 1993). Poor irrigation water quality has become problematic due to the mixing of River Awash with Lake Beseka and the thermal springs triggered by the expansion of sugarcane plantations. The springs and groundwater aquifers are inherent of poor quality, having high total dissolved salts (>1000 mg/L) (Furi 2011). However, soil profile studies in salt-affected areas found that salinity decreased with soil depth, indicating the upward capillary movement of dissolved salts (G/Selassie, 1993).

2.4 Variability in soil salinity across target areas

Spatial variability in the causes and current status of saline-sodic soils across different target areas was explored by the ICBA-RAMSAP project using geo-statistical techniques. The soil survey data was used for soil characterization, and the development of surface salinity (0-30cm) maps for Afar, Oromia, Amhara, and Tigray regions (Qureshi et al., 2018). Results showed that the electrical conductivity of the soil saturation paste extract (ECe) ranges from non-saline (<2dS/m) to extremely saline (>15 dS/m). In the Afar region, 58% of the soils are affected by different salinity levels, with highly salty surface soils situated in the region's north-eastern part (Figure 1). Surface soil salinity levels were less severe in Amhara and Oromiya regions. Only 11% of the area was affected by low to moderate salinity, and about 1% was characterized as high and extremely saline (Figure 2). In Tigray, 71% of the surface soils are classified as moderately saline. The regional variability in the salinity level is related to the history of irrigated agricultural practices in the study sites and differences in the concentration of soluble salts in the parent materials and irrigation water quality (Worku et al., 2019).

The ICBA-RAMSAP project also explored irrigation water quality appraisal and hydro-chemical characterization of water samples. Water samples were collected from different irrigation water sources (groundwater, diversion from the river, main canals, field canals, drain channels, and lake water). Results showed that groundwater and drain canals are poor (Worku et al., 2019). The same study also reported a high concentration of Na and other primary and halide anions (CO3, HCO3, SO4, Cl) in the groundwater compared to other sources in Amibara, Dubti and Kewot irrigated areas, while those from the Ziway Dugda area were classified as moderately saline waters (Worku et al., 2019). The irrigation water samples collected from Kewot and Raya Alamata irrigated areas were non-saline to moderately saline suggesting less concentration of soluble salts in the parent materials and ground water in these areas (Worku et al., 2019).

In smallholder farms, salinity problems increase when farmers use poor quality water from dugwells for irrigation during the dry season when freshwater availability from the river is insufficient to meet irrigation demand. In a baseline socio-economic survey, the majority of respondents (86%) reported poor quality irrigation water as the primary cause of secondary salinization, followed by poor land leveling and poor irrigation practices (over-irrigation and insufficient drainage) (Qureshi et al., 2018).

In summary, increasing salinity problems in the irrigated areas, particularly in the Awash basin, is causing substantial socio-economic and environmental issues (e.g., reduction in crop yields declining farm incomes) in Ethiopia. Given the pressing food needs for the increasing population (currently estimated 112 million), mitigating soil salinity to increase crop productivity of existing salt-affected soils and prevent further salinity spread is of paramount importance for agricultural development in Ethiopia. In light of the current policy drive to expand irrigated wheat production in the lowland plains, it is necessary to identify best adaptation and mitigation practices for salinity management to avoid the spread of salinity in the newly developed irrigated areas. Appropriate irrigation water and soil management practices must be integrated with on-farm soil and water management practices. The historical and current salinity management strategies and policy priorities in Ethiopia will be discussed in the following section.

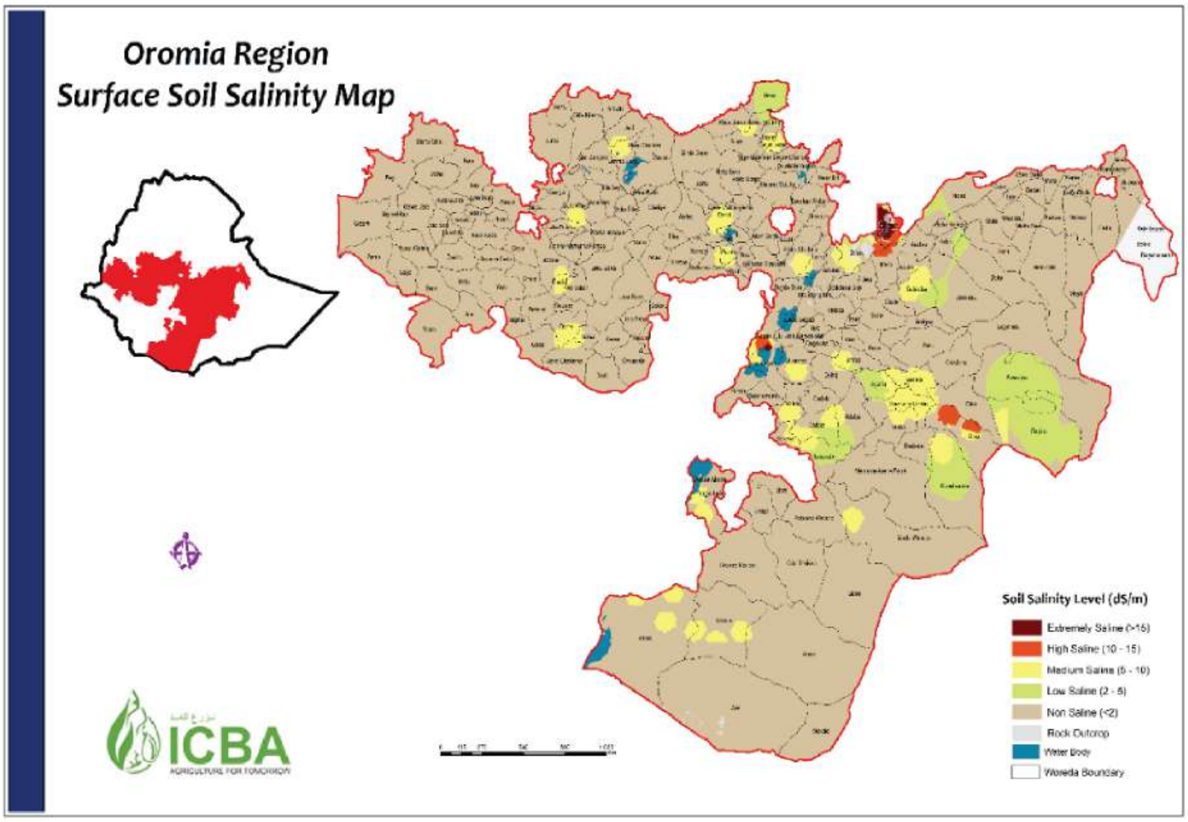

Figure 1. Surface salinity map of the Oromia region, Ethiopia

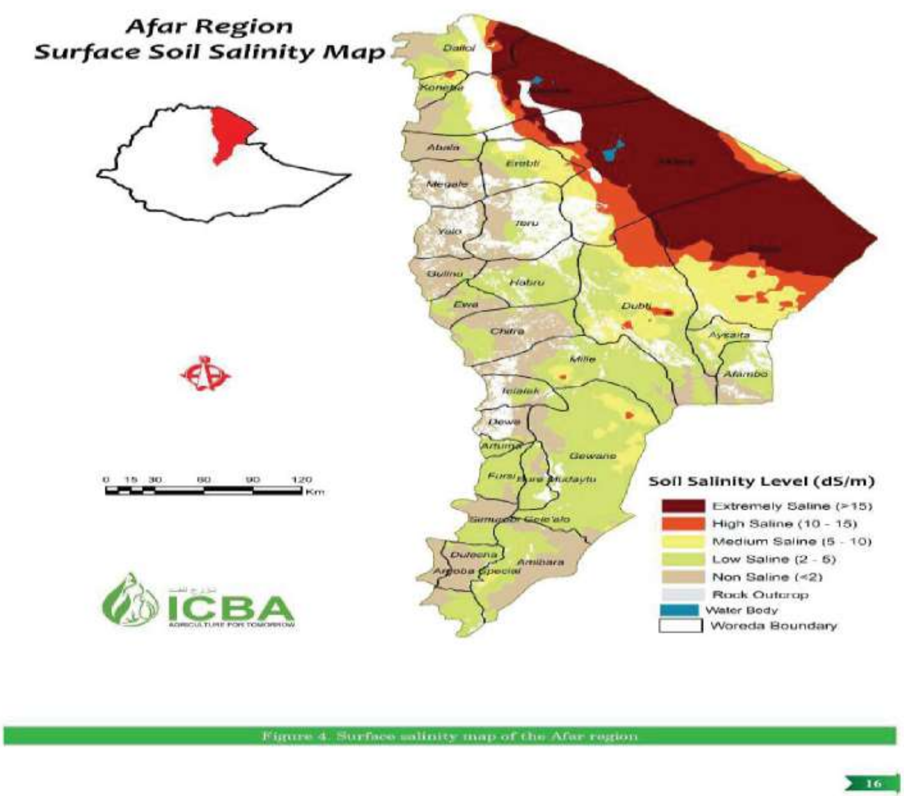

Figure 2. Surface salinity map of the Afar region, Ethiopia

03 CURRENT STRATEGIES FOR SALINITY MANAGEMENT

Desalinisation and desodification of salt-affected soils and prevention of secondary salinization of potentially salt-affected soils can be done by adopting several management strategies. These include a combination of the following:

(1) good soil management practices such as maintenance of pH and structure of soils, practicing minimum tillage to avoid soil compaction, proper seedbed preparation, and land leveling to avoid salt accumulation, enhancement of soil surface cover (mulching), crop reside and organic matter management, crop rotation, minimum fallow periods;

(2) hydraulic measures such as the use of good quality irrigation water and introduction of appropriate drainage systems (surface or sub-surface), ensure leaching (pre and post-planting) to remove salts from rooting zone, and efficient on-farm water management practices to avoid over-irrigation/flooding, based on ETo crop requirement;

(3) bioremediation or biological reclamation practices (biosaline agriculture), including selection and planting of salt-tolerant plant species or halophytic forages, are best practice options in the high salinity areas where the growth of regular field crops is restricted, which could bring these soils back into production; and

(4) in the case of sodic soils, chemical amendments such as the application of calcium in the form of gypsum ($CaSO_4$), followed by leaching out of the sodium. When gypsum is applied on calcareous soils, it reacts with water to form sulphuric acid (H_2SO_4) that neutralizes sodicity (CISEAU/IPTRID/FAO, 2005; Qureshi et al., 2018). In addition, $CaSO_4$ directly supplies Ca that replaces exchangeable Na forming $NaSO_4$, which is then leached down from the root zone.

A combination of the above methods may be practiced to control and/or minimize salinity and sodicity and halt further development of soil salinity. Choice of suitable strategies should be based on results of detailed studies and analysis of the factors leading to salt build-up and their practical management for utilization.

3.1 Current research and extension priorities

We have reviewed the national agricultural research and extension policies and strategies of the government of Ethiopia from the past and the present to explore planned interventions and priorities to rehabilitate large tracts of salt-affected soils in Ethiopia. However, despite vast areas of salt-affected soils with a high possibility of spreading in the country, there are little or no standardized research, extension, and development strategies to alleviate the problem.

The more recent soil fertility initiative formulated by the soil fertility directorate of MoA underscores the dissemination of new chemical fertilizer products based on crop and soil needs and soil amendments such as lime for acid soils and gypsum for saline/sodic soils (MoA, 2017). The strategy document puts a concrete program of work for acid soil reclamation focusing on applying lime on tens of thousands of hectares of land in the highlands. Many lime production facilities have been established around the areas most affected by soil acidification. No such elaborated action plan is available for the production and dissemination of gypsum as the currently proposed solution for the amendment of saline/-sodic soils. International experience shows severe financial and technical constraints (e.g., deep plowing, local production, and supply) to sustainably apply such chemical-based solutions to reclaim saline/sodic soils (Vargas et al., 2018).

The revised strategy of the MoA aimed at transforming agriculture by providing demand-driven and market-oriented extension services to farmers, pastoralists, and agro-pastoralists (MoA/ATA, 2017). This holds partly true for the crop-based highland farming system where MoA promotes crop technologies but not for the pastoral lowlands. The extension package for the highland cereal system is composed of improved seed, fertilizer, and pesticide to increase yields of staple cereals, namely maize, wheat, teff, barley, and sorghum. In this agro-ecology, the identified soil-related problems are soil acidity and waterlogging. An elaborated extension package such as liming and application of compost and blend fertilizer (NPS blended with Zn +B) is highly popularized. Broad bed furrows are promoted as means of draining the excess water in Vertisol areas. This is mentioned in the soil fertility strategy (MoA, 2017).

Priority issues and strategic interventions identified for agricultural extension in the pastoral lowlands in the revised extension strategy of Ethiopia are (1) livestock feed and water supply (pond construction) to increase livestock productivity; (2) veterinary extension service provision including mobile clinics and training community animal health workers; and livestock marketing system development (MoA/ATA, 2017). The extension document does not provide any strategy plan/priorities for ameliorating saline/sodic soils (see MoA/ATA, 2017). Given the importance of livestock for pastoral livelihoods, the research and extension priorities mentioned above are essential. However, these should have been implemented without neglecting the land management, including the rehabilitation of salt-affected soils, which is the basis for agricultural production.

The agricultural extension system is organized under the ministry of agriculture (MoA) to disseminate and demonstrate technologies to farmers and create incentives for their large-scale uptake and implementation. The small-scale irrigation directorate of MoA focuses on constructing irrigation structures for household irrigation in the moisture deficit areas. The soil fertility directorate of MoA is mandated to introduce best practices to rehabilitate saline/sodic and acidic soils. As such, the directorates involved in the rehabilitation of saline/sodic soils are the soil fertility directorate and irrigation water management. The former is responsible for the formulation of extension packages and scaling up of best practices to rehabilitate salt-affected soils and prevent the spread of salinity. It is also responsible for preparing guidelines and policy documents and awareness creation among policy makers regarding the problem of saline soils and preparing training manuals for capacity building for Development Agents (DAs).

Given the current government interest to expand irrigated wheat production in the lowlands for national food security, the soil fertility management directorate is mandated to demonstrate best practices available for the rehabilitation of salt-affected marginal lands and the protection of newly developed areas from the spread of salinity. However, the soil fertility directorate was unable to formulate an extension package for saline/sodic soils management apart from collaborating with ICBA and EIAR to implement the RAMSAP project. However, a recent promising development is launching the Lowland Livelihood Resilience Project (LLRP) financed by the Ministry of Peace (MoP) and implemented by the soil fertility directorate of MoA. One of the key objectives of this five-year project is to disseminate salt-tolerant crop and fodder species in 20 districts (seven each in Oromiya and SNNPR, and six in Afar states). This offers an excellent opportunity to scale up the RAMSAP-validated biosaline approach in areas where soil salinity is prevalent. We anticipate that the experiences of LLRP would provide a stepping stone to formulate extension packages for saline soil management.

The Ethiopian Institute of Agricultural Research and the Regional Research Institutes (RARIs) are mandated to generate data, information, and technologies for the country's appropriate soil and water management. The soil and water research strategy of identified salt-affected soils (saline/sodic soils), also known as “special problem soils,” proposes gypsum application but does not provide any road map for their rehabilitation (EARO, 1996). Regarding gypsum application, no research and data have been generated on the quantity of gypsum applied or the method and depth for incorporating/mixing it into the soil. In this regard, pastoral-based research centers (RCs) have been established in Dubti-Semera RC in Afar, Ziway/Adami Tulu RC in Oromiya, Shewa Robit RC in Amhara, and Alamata RC in Tigray.

3.2 Hydraulic and engineering approaches

During the military regime (1974-1991), soil and irrigation department under the Ministry of State Farms (MoSF) was established to monitor soils and irrigation water salinity levels. The department set leaching and drainage experiment stations at Melkasadi and Dubti. A leaching experiment conducted in Melkasadi was aimed at exploring the effectiveness and efficiency of sub-surface drainage systems. The study found that 40 to 60 m drain spacing with red-ash filter material with plastic or clay pumps was best to reduce soil salinity and control groundwater table (Abegaz and Tadesse, 1996). Leaching studies revealed that intermittent leaching practice with 150 mm of irrigation water effectively removes soluble salts from the root zone. The same study showed that leaching alone was not sufficient to reduce the salt concentration due to rising levels of saline ground water. In a large-scale leaching and drainage trial at Dubti (lower Awash), intermittent leaching to a depth of 20cm combined with sub-surface drainage resulted in a significant reduction of soil salinity (Ngeborg, 1986).

Based on the large-scale trials at Dubti station, the MoSF recommended leaching and plastic and clay pipe-based sub-surface drainage allied with different spacing and drainage depth combination with sub-soiling for the heavy clay soils. However, these strategies proved less effective due to the rise of ground water levels resulting from the ooding/basin method of irrigation. Rising groundwater leads to waterlogging of the root zone and ultimately to soil salinization. In addition, the combination of leaching, sub-surface drainage, sub-soiling was recommended for the heavy clay soils. In addition, mole-cross-drainage that releases water from the mole drains through percolation materials to the pipes of more profound, broader spaced drainage systems was recommended. Mole drains (channels left by a bullet-shaped device pulled through the soil) are cheap to install but last two to three years (Mashali, 1997).

The hydraulic and engineering approaches met many challenges, including high cost and technical complexity that low adoption even by commercial farms. The hydraulic solutions are unaffordable at the small-scale farm level. The Dubti research station suggested camber beds of 6-8cm width combined with drainage ditches as alternative solutions. Still, local communities showed little interest because they have high labor demand and the time required to build the structures (Ngeborg, 1986). Hence, towards the end of the military regime, the MoSF recognized the unsustainability of the engineering solutions to rehabilitate salt-affected soils under Ethiopian conditions. At the time, there was some initial effort to explore appropriate cropping patterns and crop rotation systems that involve salt-tolerant crops (mainly focused on broom sorghum) and fodder species (Abegaz and Tadesse, 1996; Ngeborg, 1986). But these efforts were cut short following the change of government in 1991.

3.3 ICBA experience with the biosaline approach

ICBA introduced biosaline agriculture as an economical and practical approach to using salt-affected lands for growing food and fodder crops. The ICBA-RAMSAP project conducted field demonstrations in selected pilot sites. More than 25 genotypes of different food crops (barley, quinoa, sorghum), forage grass (Rhodes grass, buffel grass, Panicum, etc.), forage legumes (alfalfa), and shrubs/trees (sesbania) were introduced that are suitable for salt-affected lands. These genotypes have been tested under local conditions to evaluate their response to different salinity levels. Based on the results, crops have been recommended for other regions (Worku et al., 2019).

3.3.1 Salt tolerant food crops tested

Studies have shown that barley, sorghum, and quinoa have tremendous growth and adaptation capacity in various environments, including marginal lands with moderate salinity (Hussain et al., 2020). Barley is among the five essential staple kinds of cereal widely grown in Ethiopia's higher altitude highlands (>2500 masl). The ability of the crop to withstand salt-induced stress has been well-described, but its introduction and potential use under marginal environments are not common in Ethiopia. But in some areas such as Ziway Dugda lowlands of Ethiopia, farmers shifted their production from maize and other horticultural crops to barley when soils become salt-affected.

Quinoa is not known as food grain cereal in Ethiopia, but it is attractive due to its good salt tolerance, high yield (average of 1.7 tha-1), and nutrition value. This crop's scaling up and dissemination may require the proper variety release process through the national research system. The crop is currently attracting global attention due to its high tolerance to different abiotic stresses, including good performance in marginal lands of several countries of Central Asia (Kyrgyzstan., Uzbekistan, Tajikistan) and the Middle East (Egypt, Lebanon, Iraq, etc.) (Hussain et al., 2020). Host farmers in the intervention areas expressed interest in quinoa for its high yield and nutritious values (Worku et al., 2019).

Although not included in the ICBA-RAMSAP study, there are many teff varieties and accessions that are salt- and drought-tolerant. Earlier research screened ten accessions and five types of teff for salinity tolerance and found that accession 237186 and variety DZ-cr-37 were salt-tolerant even when exposed to high salt concentrations (8 dSm-1) (Asfaw and Danno, 2011). Ethiopia is the center of origin and diversity, including barley, sorghum, teff, etc. Therefore, there is an excellent potential for the differentiation of genotypes among the available gene pool and the screening of best-suited alternative salinity crops for the existing cropping systems. A large and unexplored genetic variation can be harnessed to improve the salt tolerance of field crops (e.g., rice, cotton, etc.). During the key informant interviews and discussions, it was noted that some cotton varieties, such as Acala, can tolerate salinity levels as high as 16 dSm-1.

3.3.2 Salt-tolerant fodder crops tested

The project has generated essential data and information on selected salt-tolerant crops and fodder species of economic importance when integrated with appropriate irrigation water and soil management (Qureshi et al., 2018; Worku et al., 2018; Worku et al., 2019). The most promising fodder species included Rhodes grass (Chloris gayana), and alfalfa (Medicago sativa) that showed high salt stress tolerance and excellent biomass yield. The establishment and product of Rhodes grass were imposing, which allows regular cuttings (ICBA-EIAR, 2019).

Rhodes grass and alfalfa have been widely used on large areas in farmer demonstration plots and state and private cattle farms in Ethiopia since the late 1960s. Still, their cultivation has been discouraged due to their high water intake (Qureshi et al., 2018). It was possible to obtain up to 71 tha-1 at first harvest and 60 tha-1 at the 3rd and last harvest with 23kg N + 61.5-ton cow dung per ha (Worku et al., 2018). However, more important is the remarkable improvements in soil quality following the cultivation of salt-tolerant grasses. There was a reduction in soil salinity level from mean ECe of 12.3 to only 3.7 dSm-1 in the topsoil layer following Chloris gayana and Panicum antidotal (Qureshi et al., 2018).

Promising results were obtained for Coloured Guinea (Panicum coloratum) and Sudan grass (Sorghum × drummondii) in certain areas. Sudan grass was fascinating to farmers because of its fast growth and good palatability to cattle. In addition, the grass remains green for most of the year, providing large quantities of fresh fodder during the dry season. Buffel grass (Chloris ciliaris L) shows good adaptation to drought and saline soils and can grow with 250 to 350 mm of annual rainfall (Giorgis et al., 2010).

Sesbania (Sesbania sesban), a forage legume/tree, showed excellent potential for salinity and moisture stress tolerance in addition to excellent biomass yield. It also has a wide range of uses, such as feed and fire wood. Due to its high salinity tolerance and high water-use efficiency and deep-rooting system, sesbania serves as a bio drainage plant (effective in lowering the groundwater table via bio-pumping) for areas where high salinity and canal seepage are a problem.

In summary, the ICBA-RAMSAP pilot work with its biosaline approach adequately demonstrated the benefits of cultivating salt-tolerant forage grass and legumes in areas with no yield expected from growing other field crops due to high levels of soil salinity. The diversification of alternative salt-tolerant crops and fodder species was a low-cost approach and technically feasible for local farmers. Some farmers have started growing salt-tolerant livestock forage in their backyards or even on the part of their farms. In addition to fulfilling their livestock feed requirements, these farmers can now make better cash income from the sale of feed and seed to the neighboring farmers.

What remained was to scale up the successful experiences to reach more people in salt-affected areas, increasing the impact. In this regard, a series of field days were organized to popularize the results of the biosaline approach to local communities (Figure 3). Participants of the field-days (most pastoralists) have shown keen interest in adopting fodder grasses and legumes, given the critical shortage of livestock fodder. The economic importance of livestock to the pastoral and agro-pastoral communities in the salt-affected areas is logical. This can be a significant incentive when market linkages are created for farmers to sell fodder to cattle fattening facilities or dairy farms around major cities in the lowlands (e.g., Jigjiga, Semera, Ziway, etc.).

Farmer Field Days at different locations in Ethiopia

3.3.3 Farmers' coping strategies to soil salinity/sodicity

Farmers in salt-affected areas continue to combat salinity/sodicity and manage land and water resources based on their indigenous knowledge. These include leaching practice to remove excess salts from the root zone, land leveling to avoid water logging, application of higher rates of fertilizer, compost, and farmyard manure to mitigate salinity effects on yields, growing of salt-tolerant crops (e. g., sorghum in Afar, barley in Ziway. Farming communities in the Afar area practice indigenous remedial measures such as establishing prosopis (Prosopis juliflora) stands in the farm fields as a means of biodrainage and the application of cow dung and land leveling (the duga system).

These efforts have made some improvements in isolated places. However, little has been translated into a large-scale implementation. Because research conducted to advise farmers was confined to local field-scale experiments, results are regarded as local solutions and cannot get the attention of larger farming communities. Some of the socio-economic, technical, and policy challenges and constraints that inhibit wide-scale adoption of best practices piloted by ICBA-RAMSAP and their suggested solutions are elaborated in the next chapter.

04 CHALLENGES AND OPPORTUNITIES FOR WIDE-SCALE ADOPTION

Scaling up best practices for broader adoption and institutionalization faces technological, socio-economical, and institutional problems. Challenges driven by the absence of small-scale irrigation infrastructures, incorrect perceptions, and lack of awareness and knowledge of farmers and extension advisors are also equally important. Despite these challenges, many opportunities could harness scaling up efforts such as the existing institutional arrangements (specifically, the presence of extension advisors at kebele/neighborhood level in research stations nearby), the growing demand for high-value agricultural products from the ever-increasing middle-class population, and the increase of innovative young farmers in the community. These kinds of scaling, institutionalization and wide-scale adoption challenges are discussed in this section concerning the best practices of the RAMSAP project. For each of the identified challenges, possible solutions and existing opportunities are highlighted.

4.1 Limited awareness among farmers and extension workers

Socio-economic baseline survey in the target areas of Ethiopia and South Sudan revealed that limited awareness and information about the causes of salinity among farming communities results in limited ability to take appropriate measures to mitigate salinity (Qureshi et al., 2018). The report also indicates that the frontline extension workers, who are the primary source of agricultural information, should be trained in the basic skills and knowledge about salinity. This suggests that increasing awareness and capacity among farmers and extension workers is of utmost importance for preventive measures against the worsening soil salinity and sodicity conditions. In addition, the lack of trained human resources to manage irrigated agriculture was among the significant problems in irrigated commercial farms. Irrigation water is primarily controlled by untrained irrigation crew who have no concept of proper water application regarding amount and frequency based on crop and leaching requirements. As a result, poor water management and lack of adequate drainage facilities have contributed significantly to the groundwater build-up in a short period (G/Selassie, 1993).

Suggested Solution: Capacity building, training, and producing qualified irrigation agronomists from agricultural universities.

The limited awareness among farmers, extension workers, and irrigation agronomists points to the need to provide capacity-building training on salinity management options to extension workers and farmers alike. Farmer awareness creation can be achieved by employing local FM radios to send critical messages related to saline soil management. In this regard, the traditional means of information exchange (the dagu system) can disseminate information on saline soil management. Organizing on-job training for the extension workers require skill transfer and exchange visits. Short-term training of relevant practitioners at all levels, including experience sharing study tours in the field of irrigation water management and irrigation agronomy, would be necessary. The extension workers are graduates of the Agricultural colleges, but the training lacks practical field attachments to irrigation sites. This calls for institutional capacity and strengthening of agricultural education and training effectiveness, including curriculum revision to include practical training on irrigation water management.

Further, the lack of on-job training and other field level incentives (e.g., transport such as motorbikes) to stay in their position and perform as expected is often weak. This needs to be addressed by the policymakers at MoA. The envisaged plan was to assign a team of extension workers composed of an expert in natural resource management, livestock/veterinary, crop agronomy, and cooperative development experts at Farming Training Centres (FTC). The team of Development Agents (Das) in Ethiopia is expected to support farmers in knowledge and information transfer and demonstrate modern production practices, which in turn enhance the adoption of modern agricultural technologies and subsequently increase productivity.

4.2 Lack of good quality seed

The supply of good quality fodder seed is a significant scaling challenge to disseminate the salt-tolerant crop and fodder species and varieties. The promising salt-tolerant fodder grasses (Rhodes grass, Sudan grass), legumes (alfalfa), and food crops (barley, quinoa, and brush sorghum) have already been identified and screened by the RAMSAP project. Studies in other parts of the country have indicated that most of these species are heavy seeders to ensure germination under fallow with no or light cultivation and produce enough hard seed to persist in the cropping system. Many indigenous forages grow in the dry regions of Ethiopia, which can be used as feed. This germplasm can be evaluated and promising species identified for incorporation into livestock production systems. However, there is no public institution that is mandated with fodder seed multiplication in Ethiopia and South Sudan. The seed enterprise in these countries is engaged with the multiplication and distribution of the seed for staple cereals (maize, wheat, barley, sorghum).

Solutions and opportunities – Seed multiplication in research centers, FTCs, and on-farm fields

In Ethiopia, the lowland RCs such as Melkawerer RC and Dubti-Semera RC in Afar, Ziway RC in Oromiya, Shewa Robit RC in Amhara, and Alamata RC in Tigray gives an excellent opportunity for bulk seed production of selected forage species. In addition to FTCs, the research centers can allocate land for bulk seed production. The International Livestock Research Institute (ILRI) can offer seed and technical information on forage development work. Teaching, research, and community service is the mandate of universities. Therefore, conducting action research on fodder grasses/legumes and bulk seed production can be negotiated with the regional universities.

With increasing degradation of the pasture and critical shortage of livestock feed, there is an increasing trend of developing backyard fodder reserves among pastoralist communities (Elias, 2008). This offers opportunities for forage seed multiplication. The experience of innovative and model farmers who have already started backyard fodder production can be used for forage seed production with some level of training and technical assistance. The newly launched LLRP and NGOs/development partners can assist in purchasing seed from producer farmer groups for distribution to other farmers. Farm saved seeds have already been collected from the farmers who participated in the RAMSAP project. Possibilities of seed production locally should also be assessed.

The experiences of the Agricultural Growth Programme (AGP) and Capacity Building for Scaling up of Evidence-Based Best Practices to Increase Agricultural Production in Ethiopia (CASCAPE) in the high potential highlands of Ethiopia could be helpful in this regard. These projects have set up seed multiplication groups around regionally prioritized crops (e.g., Irish potato, sorghum, etc.). The Woreda Office of Agriculture purchases seeds to distribute to other farmers. The regional seed enterprise provides technical support in seed quality control and certification. The experience can be scaled out/up in the salt-affected lowland areas as well.

4.3 Policy misperceptions towards pastoral lowlands

The arid and semi-arid lowlands that account for approximately 57% of the land area of Ethiopia are inhabited by (agro) pastoral communities. In this area, the salt-affected soil naturally occurs due to geochemical processes and inappropriate water management when irrigated agriculture is practiced (Furi, 2011). The pastoral production provides an immense contribution to the national economy by raising 40% of the cattle, 75% of the goats, 25% of the sheep, 20% of the equines, and 100% of the camels (Arsano, 2000). However, a fundamental misunderstanding of the pastoral mode of production seems to exist in terms of land use and land management under pastoral production systems. Due to the pastoral land use system based on seasonal mobility, pastsoralists are considered difficult to administer and implement tax revenue collection. Hence, there has been a limited effort to mainstream pastoral land management in the national policies and programs. Because pastoralists move over a large area searching for pasture and water for their animals, policymakers believe that pastoral lands have no potential for agricultural production unless irrigated and are considered unproductive and left for ranches and national parks (Elias and Abdi, 2010). As a result, little research, extension, and development assistance have been directed towards land use management in the pastoral lowlands.

This policy misperception lies at the root of the absence of elaborated extension package and land management plans for the pastoralist lowlands, including saline soil management, which is in direct contrast with the highlands. This lack of research, extension, and development intervention, even when irrigated agriculture is practiced, has exposed the already fragile ecology (shallow groundwater with high Total Dissolved Salts [TDS], low precipitation, high ETo rates, etc.) and the extent of land degradation such as severe soil salinization/sodication (Furi, 2011).

Solutions/opportunities - Create increased awareness among policymakers

In general terms, this goal can be achieved by opening a dialogue with policymakers to improve their understanding of the problem and its future implications. This can be achieved by organizing high-level policy excursions to field sites, meetings, and workshops to open dialogue. The production and distribution of policy briefs and technical papers based on in-depth thematic studies and establish thematic platforms such as research-extension platforms saline soils at regional and national levels. In the context of the irrigated drylands, the pastoralist standing committee of the parliament could be an essential vehicle to channel information and lobby for land use and land management policy change.

The mainstream misperceptions of the dryland lowlands are slowly fading away with the current surge of interest in expanding irrigated grain production. This offers an opportunity to engage pastoralists in critical environmental issues, including developing salinity and sodicity problems. The pastoral research centers can create an opportunity to generate improved land and fodder management technologies.

4.4 Lack of inter-institutional collaboration

Concerning the management of salt-affected soils and irrigation water quality, several government institutions are responsible for the different aspects of irrigation water quality monitoring and saline soil management structured under MoWIE and the MoA. There are two relevant directorates in the MOWIE. Directorate of hydrology and water quality, and the directorate of irrigation water resource allocation, distribution, permit, and management. The former is responsible for inspecting irrigation water quality, including checking the salinity levels of rivers and lakes. On the other hand, the latter is responsible for the issuance of irrigation water use permits. However, our key informant interviews revealed no communication and coordination between the two directorates of the same ministry in terms of irrigation water management. For instance, the hydrology and water quality directorate inspects the salinity levels of Lake Beseka and finds it to be saline. Therefore, it recommends the diversion of lake Beseka water to the Awash River water with the assumption that the salt will get diluted when mixed with the flowing water of the river. On the other hand, the irrigation water management directorate permits farmers to use saline water to irrigate the downstream large-scale commercial farms. This increases the salinity/sodicity of the irrigation water for the downstream catchment (lower Awash basin) and leads to salt build-up in the soil because of the mixing of the saline L. Beseka with Awash river water.

In the same way, the relevant directorates within the MoA should focus on small-scale irrigation and the contruction of irrigation infrastructures for household irrigation in the moisture deficit areas. The extension organizations should be mandated for validation and scale-up of best practices in saline/sodic and acid soils management.

The agricultural research centers should test and validate promising options and technologies on soil and water management, including irrigation agronomy. But apart from collaborating with the RAMSAP project, there is no institutionally embedded strategy on remediation of salt-affected soils on the part of the research. In addition, the research work is delinked from the extension. Except on some project-based joint activities such as the RAMSAP, there is virtually no coordination and communication with the extension directorate of MoA responsible for formulating extension packages for uptake by farmers.

Suggested solutions:

a) Establish a solid inter-institutional collaboration mechanism between appropriate units of MoWIE, MoA, EIAR, and RARIs with mandated zonation for managing saline soils and irrigation water quality. Coordination and concerted actions are needed to enhance collaborations, experience exchange, and avoid duplicated efforts in rehabilitating salt-affected soils. Similar institutes need to be established under the MoA and Directorates of research in South Sudan.

b) Establish a national research-extension and development platform to restore saline/sodic soils and protect the newly developed areas. This can be organized under the auspices of the soil fertility directorate of MoA.

c) The new policy move towards expanding irrigated wheat production in the lowlands, in a way, brings the opportunity to strengthen inter-institutional linkages and collaboration. Since 2019, Prime Minister Dr. Abiy Ahmed initiated irrigation-based wheat production in the lowlands and rainfed production in the highlands to be grain self-sufficient, transforming the country from a net wheat importer to exporter. There are plans to develop an additional irrigation area of 660,000 ha (MoA/EIAR/EARCS/ATA, 2020). EIAR is a leading inter-institutional task team composed of the soil fertility directorate of MoA, relevant units of the MoWIE and ATA. This task force needs to advise higher policy to assign a coordination body to regulate irrigated farms in terms of halting the spread of salinization/sodification. While more emphasis is given to the development of irrigation infrastructure, the management and sustainable use of irrigated lands needs attention to prevent waterlogging and soil salinization problems.

d) Diversion of saline water from the Beseka Lake into the Awash River needs to be stopped. This not only transfers the problem from one ecosystem (lake) to the other (freshwater river), but it also worsens soil salinization as large tracts of lowlying lands are irrigated by saline water.

e) Capacity building training should be arranged for the experts at the appropriate units of the MoWIE, MoA, and EIAR/RARIs on priority topics such as irrigation water quality inspection, soil management, including environmental impact assessment of the newly established farms. Given the new plans to develop tens of thousands of hectares for irrigated wheat production, technicians are needed to ameliorate the existing soil salinity problems and prevent the further spread of salinity in the irrigated areas.

4.5 Lack of institutionalization of the best practices

Often, it is hard to reach high government officials. There is hardly any room for institutionalizing new approaches and best practices which has been recommended by the projects such as RAMSAP.

Solutions/opportunities:

- Involvement of all stakeholders in the bottom-up planning process and preparation of district development plans.
- Starting from the second growth and transformation Plan, the governments need to promote a bottom-up planning process that would give greater power to district-level administration to initiate and determine integrated plans for agriculture and rural development. This is an

excellent opportunity for projects such as RAMSAP to streamline and incorporate validated practice to rehabilitate the salt-affected soils in the agricultural development plans. The participation of the project field staff in the district development plan preparation can create an ample opportunity to incorporate the regionally applicable best-fit practices into the district plans. It also results in some spontaneous adoption of piloted activities and interventions. By closely working with the district offices of agriculture, it is possible to incorporate best practices into their development plans. Often, participating districts can incorporate Project-tested best practices in their annual programs and allocate a budget for their implementation. This was conceptualized as organic scaling up or spontaneous adoption

- Engage government officials at all levels – district, zone, region, and national levels.
- It is essential to get the buy-in and trust on the outcomes of the piloted activities in target areas. In particular, engagement with the extension system, such as placing a senior extension staff at the extension directorate of MoA plays a significant role in facilitating the process of scaling up and institutionalization
- Establishing institutional arrangements such as senior advisors and regional and technical committees composed of representatives from the Bureau of Agriculture (BoA), RARI and universities at various levels helps develop trust and confidence in the technology being piloted.
- Joint activities involving extension experts at district level, researchers from RARIs and regional universities, and farmers enable institutional embedding of the piloted approach. Some farmers copied the technology just by visiting the field of the host farmers and from the information they got about the merit of the best practices from development agents and others.
- The involvement of experts from regional and federal extension departments in preparing best practices creates a sense of ownership of the best practices. It paves the way for their incorporation in the national/regional extension packages.

05 RECOMMENDATIONS TO ADDRESS SCALIN UP CHALLENGES

There is an increasing realization of rehabilitating the existing salt-affected soils and preventing their further spread in the newly developed irrigated areas. Several technologies are readily available for the reclamation of saline and sodic soils. However, soil salinity problems are complex, and straightforward solutions do not exist. The approaches need to be multidimensional and must take into account the biophysical and socio-economic conditions of the target area and the livelihood aspects of the associated communities (Qureshi et al., 2007).

The guiding principles in planning the strategies should include (1) following a people-centered approach that deals with people, their sensitivities, resources, and livelihoods and that has a closer alignment with national/regional development plans through the bottom-up planning and demand-driven extension process; (2) adopting an integrated approach involving agro-economic (on-farm soil and water management options) and socio-economic (institutions/services, input/output prices, market linkage, farmers' knowledge, and perceptions) considerations; (3) integrating a local capacity building for farmers, extension workers/advisors at the district level and DAs at kebele level on all aspects of saline soil and irrigation water management; and (4) linking with policy – demonstrate evidence to formulate realistic and favorable policies for management of land and water in the irrigated areas; and (5) creating awareness on the extent and impacts of the problem among policymakers.

Based on extensive literature review, the following recommendations can be made for Ethiopian policymakers, extension workers, and farmers to rehabilitate salt-affected soils and halt further expansion of secondary salinization and sodification:

5.1 Promote biosaline agriculture

Under the prevailing economic conditions and low levels of technological development in Ethiopia, bioremediation is an economical and practical approach to use unproductive lands to grow food crops and fodder grasses/legumes on saline/-sodic marginal soils. This approach is based on increasing drought and salt-tolerant crops and suitable on-farm soil and water management practices. This can be a key to the future of agricultural and economic growth in the regions where salt-affected soils are prevalent, including Ethiopia and South Sudan (Hussain et al., 2020).

The biosaline approach is advantageous because it increases economic benefits and solves the problems of saline effluent disposal. It can also effectively assist in lowering the groundwater table (via bio-pump) to reduce waterlogging and consequent salinity in irrigated areas (fodder trees/shrubs serve as biological pumps). Based on this, some researchers argue that biosaline agriculture is of special importance in Ethiopia and South Sudan for the following reasons (Qureshi et al., 2018):

Forage production on saline soils can help increase the livestock productivity constrained by feed shortage in the dryland lowlands. Many prime grazing and water points are being converted into irrigation farms (state or private) and, in some cases, for ranching. The expansion of invasive Prosopis species in the Afar rangelands has overtaken much of the formerly prime grazing sites. The conflict between various pastoral groups for pasture and water – Argoba with Karayuu, Karayuu with Afar, Afar with Somali (the Isa tribes) has resulted in cattle raids and loss of life. Add to this the expansion of saline-sodic soils that further marginalize the lives of the (agro) pastoral communities. In the face of all these challenges, introducing salt-tolerant and high-yielding fodder grasses and legumes is of paramount importance. These can be disseminated through backyard forage production schemes and the integration of forage legumes into cereal production systems.

Engineering solutions to waterlogging and soil salinization in irrigated agriculture are expensive and technically complex for low-income countries. Such options often cause water pollution and environmental degradation when drained water containing high soluble salts and sodium mixes with irrigation water. Under these conditions, bio-drainage cauld be a viable option to control the rising groundwater table above critical depth for crop growth. Exploring the possibility of bio-drainage for waterlogged saline lands through the plantation of salt-tolerant trees (e.g., sesbania sesban) can reduce the volume and cost of drainage.

In Ethiopia and South Sudan, large tracts of agricultural lands have become barren and abandoned due to poor soil and water quality conditions. Since the growth of regular crops in these soils is not possible, planting halophytes can be a viable solution to produce food, fuel, fodder, fiber and essential oils, and medicine that are much needed by the growing population. By adopting these strategies, unused and marginal lands can be brought under productive use, contributing to national food security.

In this regard, the demonstrated evidence of the ICBA-RAMSAP project has generated scalable experiences and best practices as outlined earlier. These tested practices in target areas should be scaled out to more expansive areas where salt-affected soils are prevalent. To fully exploit the full potential of halophytic and other salt-tolerant plant species, there is a need to increase the performance of plant species used to manage salt-affected soils.

5.2 Improve drainage and leaching systems

The salinity problem results from inadequate provision of drainage and poor water management, including the use of saline (ground) water for irrigation. In this regard, the use of crops and varieties that can tolerate high salt levels may form an intermediate strategy. In all field-based reclamation activities, a balance between irrigation, leaching, and drainage must be kept to prevent irrigated lands from excessive waterlogging and salinity problems. In large-scale irrigated farms, adequate drainage systems should be a critical component for rehabilitation activities. Therefore, it is essential to make a comprehensive cost/benefit analysis associated with constructing drainage facilities or repairing and functionalizing the existing damaged infrastructures developed by the state farms. This is crucially important in the context of the renewed interest to expand irrigated wheat production in the semi-arid lowlands of Ethiopia.

FAO guidelines for rehabilitation drainage systems should be applied to these systems (FAO, 2007). Timing of leaching (intermittent, regular, etc.) should precede the critical growth stages at which stress should be prevented. Studies found that periodic leaching is more effective than continuous leaching (Chanduvi, 1995; Rhoades, 1995). Since salt is often more damaging to seedlings than to mature plants, applying leaching water is more effective during a pre-plant irrigation to reduce salt in the seed zone and reduce salinity through the soil profile (Al-Hiba, 1995).

Several leaching and drainage experiments have been conducted in the middle and lower Awash valley (Dubai, Amibara, and Melkasadi) in Ethiopia and stated promising options to reduce salt concentration in the root zone area. However, high financial, material, and labor costs coupled with sheer lack of awareness and knowledge about the saline/sodic soils among the local communities and the managers and the irrigation crew of the irrigated farms have failed to implement the available solutions. In South Sudan, access to irrigation water is a major problem in increasing crop productivity. Farmers having access to groundwater usually irrigate more than those who do not have this facility. Therefore improving irrigation efficiency is vital to control excess water from the root zone and control waterlogging problems. The excessive use of saline groundwater may accelerate the development of salinity in irrigated lands.

5.3 Improve on-farm water management

The inefficiency of irrigation is the single most important cause of land degradation by waterlogging and soil salinity. Water application above crop and leaching requirements has contributed significantly to waterlogging, groundwater build-up, and soil salinization. Hence, it is crucially important to avoid ooding/basin method of irrigation and adopt efficient irrigation methods (requirement, frequency) based on ETo and crop requirement. Sprinkler irrigation allows control of the amount and distribution of water (Mashali, 1997). To this effect, it is essential to develop agricultural water management manuals, bulletins, and yers as guides for better water management practices. Here, the role and concerted effort of the hydrology and irrigation water quality departments and the soil fertility directorate of MoA are crucially important.

5.4 Limit saline water use for irrigation

Diagnostic studies in the target areas found that poor quality irrigation water (mainly from wells, lakes) having high soluble salts increases the soil salinity, which hampers both the soil productive capacity and the crop itself. Water quality is becoming problematic in the irrigated areas of the Ethiopian lowlands. In the Awash valley, the salinity of the Awash River water is worsening, which is partly due to the mixing of the saline Lake Beseka water with the river. In this regard, the current practice of diverting the saline Beseka lake water to Awash River must stop, and other solutions should be sought to mitigate the expansion of Beseka Lake. Regular irrigation water quality monitoring is necessary as early warning systems to prevent pre-disposed areas from potential damage (Qureshi et al., 2007). The responsibility lies with the hydrology and irrigation water quality directorate of MoWIE as the quality of Awash River water itself is of marginal quality due to the mixing of River Awash with thermal springs and Lake Beseka. The in-depth hydrological study should mix irrigation water from the Awash River with Lake Beseka, the thermal springs, and groundwater aquifers with high TDS levels. In such areas with interlayered contaminated fresh and saline water aquifers, there is a need to understand the ways aquifers were contaminated. The rising groundwater tables can be prohibiting by avoiding basin and ooding irrigation systems.

5.5 Gypsum (chemical measures)

In salt-affected lands, chemical amendments such as gypsum are used to neutralize soil reactions and replace exchangeable sodium with calcium. The soil fertility strategy of MoA mentions the need for chemical modifications of salt-affected soils by applying gypsum ($CaSO_4$) as a source of calcium. However, data and information are lacking on the quantity of gypsum to treat sodic soils, method, and depth for incorporating/mixing into the soil, which needs to be a research priority. Along with the rehabilitation of saline/sodic soils, there is a need to enhance the fertility and productivity of soils. This can be achieved by increasing the soil organic matter by adding compost, farm yard manure, crop residue, or green manuring. The minimum/zero tillage practice will assist in accelerating the reclamation process of saline/sodic soils and supply plant nutrients.

5.6 Land leveling (physical measures)

Land leveling is critical in the reclamation of salt-affected soils and efficient irrigation management. Lands affected by salt should be leveled before the commencement of surface ushing. Farmers in the RAMSAP target areas are aware of the importance of land leveling and are reported to have practiced it on their farm fields (ICBA-EIAR, 2018). In other places where the best practices are to be scaled out, awareness and training should be provided on land leveling. In commercial farms, this can be achieved using simpler grader systems that can be tractor-mounted. Lack of machinery is one of the major limitations in South Sudan for implementing land levelling activities on farmer fields.

06 STRATEGIES FOR SCALING UP

As discussed in section 3.2, the ICBA-RAMSAP project has tested the importance of biosaline agriculture as a remedial measure for soil salinization in Ethiopia and South Sudan. This approach integrating crop and forage-livestock production systems is hugely important for the pastoral/agro-pastoral communities that inhabit the salt-affected areas. When combined with appropriate on-farm soil and water management practices (e.g., normal leaching/flashing), the approach forms an effective strategy to alleviate soil salinity. In this regard, the demonstrated evidence of the ICBA-RAMSAP project has generated a substantial amount of data and information on selected salt-tolerant crops and fodder species of economic importance. The project has introduced more than 25 genotypes of different food and fodder crops and shrubs that produce excellent biomass yield (e.g., Rhodes grass) under high soil salinity levels where no output is expected from cultivating other field crops. What remains to be done is to activate the extension service for scaling up these genotypes to all salt-affected areas with some level of adaptation and validation. The scalable experiences gained and best practices validated need to be scaled out to more expansive areas where salt-affected soils are prevalent.

Serious attempts should be made to generalize the local level results for wider scale dissemination through the extension systems. Since identification, documentation, and scaling up of best practices are vital components of the extension strategies, ample opportunities exist. Still, efforts need to be made to document, characterize, and scale up the ICBA-RAMSAP experiences with farmers. This chapter aims to provide policy guidelines for successful scaling and broader uptake of the best practices following a brief theoretical discussion on the conceptual issues related to scaling up/out.

6.1 Theoretical building blocks of scaling

Scaling generally refers to bringing more quality benefits for more people over a wider geographic area more quickly, more equitably, and sustainably (Menter et al., 2004; Wigboldus and Leeuwis, 2013). Simply put, the term scaling is used to refer to the adoption, adaptation, uptake, and use of innovations and agricultural best practices across a broader range of actors and or geographical areas. Scaling involves both horizontal (scaling out) and vertical (scaling-up) elements. Horizontal scaling refers to increased adoption of agricultural innovation, expanding the geographical area of innovation beyond the original intervention area covering more people and communities. Vertical scaling (scaling-up), on the other hand, refers to the institutionalization of a piloted approach within the government system involving the participation of stakeholders and decision-making at a higher level (Menter et al., 2004). However, it is an entirely separate concept of scaling up and scaling out because they are interactive processes. Some spontanous or organic scaling up process occurs when some local stakeholders integrate the best practice on their initiatives while a project is doing scaling out activities in a particular target area (Abi et al., 2018).

Scalability and the complexity level are also different in scaling out from scaling up. Whereas scaling out involves replicating the same prototype, scaling up requires adaptation and application of innovations to different contexts with involvement and interaction between many actors and institutions (Menter et al., 2004; Seerp and Leeuwis, 2013). Scaling up means system transition, and it relates directly to the scale 'levels' - from crop field level to farming system and from local to regional/national policy level. In other words, vertical scaling means crossing scale levels, while scaling out (horizontal scaling) means increased adoption within the particular scale level (Wigboldus and Leeuwis, 2013).

There has been a recent surge of interest in scaling in the areas of development, specifically natural resource management and agricultural research, because achieving impact at scale has been one of the most significant challenges in agricultural development (Schut et al., 2020). Many decades of agricultural research that developed technologies to increase agricultural productivity have failed actually to do so. In countries where smallholder farmers pre-dominantly practice agriculture, uptake of these technologies has been poor. There are various reasons for this, such as the agro-ecological conditions in which the farmer operates not being conducive for the uptake of a specific technology or the institutional setting, not supporting innovations.

Scaling up cannot be implemented in a business as a usual mindset; it demands new ways of organizing things, an innovative institutional setup, communication and knowledge generation, and a platform for sharing. Scaling is designed to stimulate a broader scale change to the target clients and the government policy, operational modalities, and institutional setup and structure (Tefera et al., 2016). Smallholders' agriculture is dynamic and subject to change as much as capital-intensive agriculture. While change is happening all the time, it can be slow or fast, deliberate or spontaneous, negative or positive. Empirical studies show that change will be positive, immediate, and more beneficial through planning and intentional action. This calls for understanding the drivers of change and harnessing these powerful influences (Figure 4). The drivers of change are enormous. They can be internal or external; they can also push or pull changes. Most often, changes happen as the result of a multitude of factors (Koomen et al., 2013).

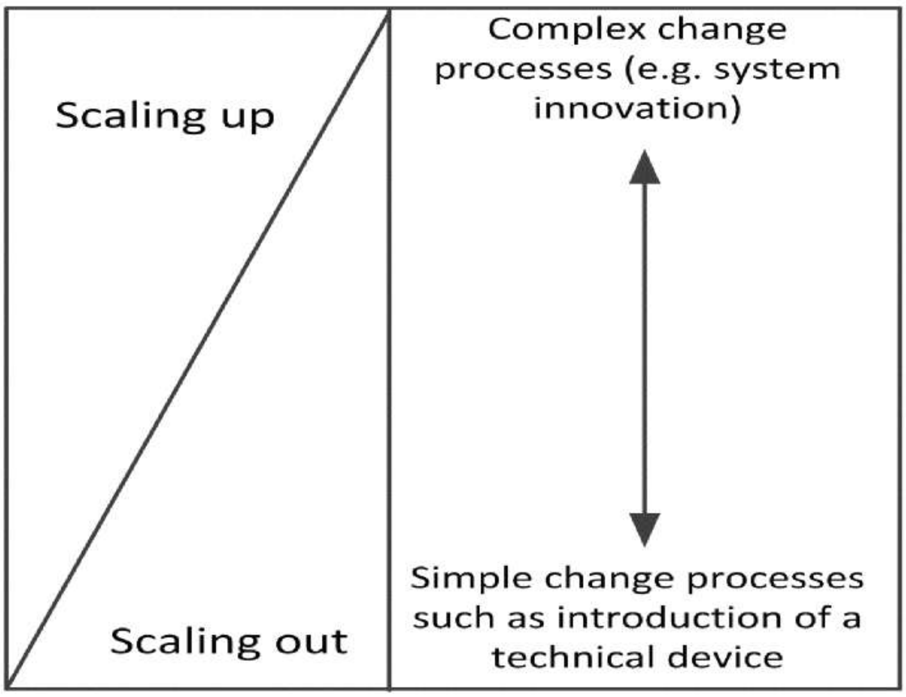

Figure 3. The interactive process of scaling out and scaling up.

6.2 How scaling is featured in the Ethiopian agriculture

The Government of Ethiopia is convinced more than ever on the importance of scaling up best practices to sustain agricultural growth and attain poverty reduction. The extension system in Ethiopia is extending a package of agricultural technologies to farmers. The core strategy within the agricultural agship program of the Growth and Transformation Plan (GTP) is to scale out and up of best practices employed by some model farmers to wider geographical areas and communities with the aim of at least doubling crop yields and effecting massive changes in the livelihoods of farmers (MoA/AGP, 2016). For this reason, the agricultural extension service focuses on identifying, documenting, and screening "best practices" involving some level of aggregation from village/kebele to district/woreda and up to the regional level.

The extension directorate of MoA has prepared best practice scaling up guidelines that outline the steps and criteria in the identification, documentation, and scaling up of best practices harvested from model farmers (MoA, 2009). The guideline indicates that extension workers (Das) are responsible for identifying best practices within their working kebeles. Any farmland with better crop husbandry and strong crop stand and livestock farming that shows better performance than the surrounding farms can be identified as best practice. DAs can get the information on best practices through discussion with communities meetings at the farmer training centers (FTC), seeking information from community leaders, and observing during regular supervision.

Criteria for best practice identification include productivity, sustainability, market demand, crop varieties, tolerance to diseases and pests, simplicity to implement, contribution to women empowerment, and the diversification of agricultural products. The DAs use these criteria to score the identified best practice on a Likert scale (1) as low, (3) as a medium, and (5) as high, based on farmers' response or during a visit to farmers' fields. The high-scoring best practices are then compiled and submitted to the woreda agriculture office for further screening and then passed to the zonal and regional level screening. At each stage, discussions are made on the merits and demerits of the best practices, and final approval is made at the regional bureau of agriculture. The regional bureau of agriculture then submits the selected agricultural best practices gathered from the model farmers all across the region and are passed to the federal extension directorate of MoA for further validation with research and scaling up by incorporating into the national extension package.

However, stakeholders' lack of clarity on the operational definition of "best practices" and "model farmers" caused significant confusion in screening and scaling up best practices in the extension system. Working with the AGP and the extension directorate, the CASCAPE project adopted an operational definition of best practices and model farmers (Elias and van Beek 2015). Accordingly, best practices are conceptualized as practices employed by "model farmers" who, through the adaptation of extension packages developed by local agricultural extension services, proved to increase crop yields substantially compared to the conventional practices. Upon careful evaluation and verification, best practices demonstrating success for the locality impact agricultural production and can be replicated.

On the other hand, model farmers use more than 70% of the agricultural extension package technologies made available to them through the extension system and adapt the package to their circumstances through local innovation. Identifying model farmers, documenting their practices, and scaling them to more expansive geographical areas and communities is a vital component of the AGP. This aims to bring the productivity of average farmers (i.e., non-model farmers) close to half the level of production of model farmers (Tefera et al., 2016). However, scaling best practices from model to non-model farmers and from one geographical area to another requires field verification and validation, generating evidence for scaling up the best practices (Elias and van Beek, 2015).

6.2.1 Understand the drivers and inhibitors of adoption

Identifying the drivers and pathways to promote more rapid and extensive adoption of agricultural technologies is a crucial step in the scaling process (Tefera et al., 2016: Koomen et al., 2013). Better understanding is needed of the factors that in uence the adoption and diffusion of technology and the inhibitors of technology adoption at various levels of aggregation (field, farm, community, etc.). Experience suggests that successful adoption and uptake of technologies depends on a favorable con uence of technological attributes, economic conditions (household resource endowment, labor supply), institutional (access to credit, market), and policy (right to land and water, pricing) factors. Only by understanding these factors will researchers, extension workers, and policymakers modify the technology, delivery mechanisms, and policy environment to stimulate successful uptake and implementation at different scales.

Understanding the linkage between drivers of technology adoption or a best practice is vital (Figure 5). For instance, climate change forces smallholder farmers to adapt to the changing scenario by adopting cropping patterns, mixing livestock types, early planting or late planting, etc. Hence, scaling up must be rooted in understanding the drivers or inhibitors of adaptation to change through adoption of best practices and scaling up of the same for the best outcome. The drivers of adoption may include technology supply, institutional support (market, extension advice, credit), population, policy, etc., which can be called push factors (Tefera et al., 2016).

The access to credit, household income, livestock ownership, farm size, level of education of household head, and a membership to a primary cooperative are among the significant drivers of the adoption of the extension package delivered to farmers. Among the inhibitors of adoption was the high cost of inputs (fertilizer, seed, etc.), labor demand (e.g., for row planting), low-profit margins, and unavailability of good quality seeds, among others (Tefera et al., 2016; Koomen et al., 2013).

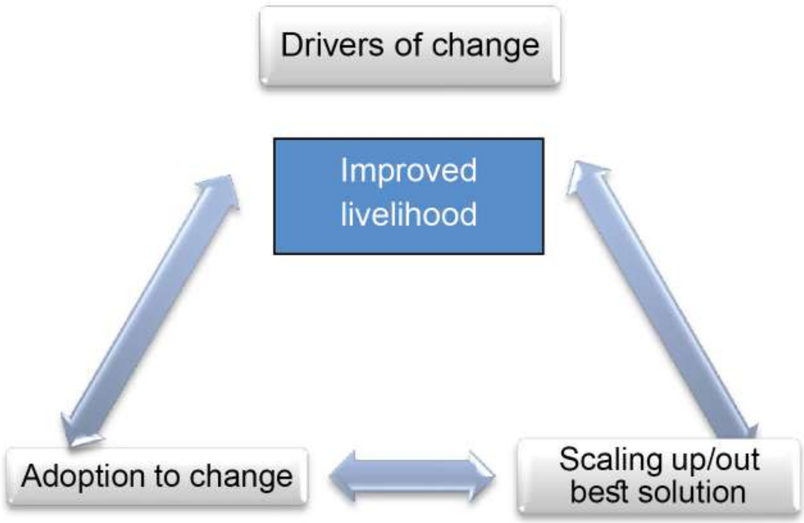

Figure 4. Linking drivers of change, adoption, and scaling up

6.2.2 Define recommendation domains and development pathways

Recommendation domains are defined as a group of farmers whose circumstances are similar enough that the same recommendation can be given (Harrington and Tripp, 1984). A variation on this definition incorporates a geographical element, places, and sets of conditions for which a particular technology is considered feasible and therefore suitable to promote (Kam et al., 2008). Recommendation domains may be defined by agro-ecological and/or socio-economic (human) circumstances (Elias, 2010). As long as there is heterogeneity among farmer groups depending on their socio-economic characteristics, farm characteristics, and wealth, then uptake of innovations and recommendations for scaling out will rely on the specific target group. Similarities in the biophysical environment such as agro-ecology, soil types, climate, topography, and socio-economic conditions (e.g., market access, extension service, livestock ownership) are essential for scaling innovations and best practices from sites of testing/piloting to areas of scaling for more comprehensive implementation (Koomen et al., 2013). Differences in agroecology affect the production potential, while differences in socio-economic circumstances affect farmers' ability to exploit the area's agricultural potential.

To give appropriate recommendations about innovations and agricultural best practices, we have to look into how the composition of the farmers is within the experimental areas, how various groups view the 'innovations', and the socio-ecological niches for a particular innovation (Ojiem et al., 2006). From this analysis, a best-fit strategy might be deduced (Giller et al., 2011). In general, blanket recommendations of technologies and innovations do not work; matching innovations to target groups can increase the successful uptake of innovations. Targeting can be done at various scales – from field to farm to the community to regional scale. Recommendations based on farm typologies (model vs. non-model farmers) as a step between understanding the drivers for adoption of innovations and horizontal scaling up or scaling out. This could be an essential step leading to the success or failure of a particular innovation, as a single technology will, for a variety of reasons, never be suitable for all farmers (Elias, 2010).

The recommendation domains discussed above relate to the concept of the development domains or development pathways defined by (Chamberlin, 2006). A development pathway represents a typical pattern of change in resource management and agricultural production, associated with a standard set of causal and conditioning factors (Pender et al., 1999). This approach identifies more comprehensive development options than the commonly taken classification of livelihood systems in Ethiopia based on one dominant criterion: moisture availability (moisture reliable, drought-prone, and pastoralist areas). This model is developed for opportunities and constraints facing alternative rural livelihoods based on agricultural production potential, labour availability and market access.

Figure 5 shows the grouping, which resulted in a total of 30 possible domains in Ethiopia. These were based on a combination of moisture and altitude (moisture reliable/highland, moisture reliable/lowlands, drought-prone/highlands, drought-prone/lowlands, pastoralist), market access (high or low), and population density as an indicator of labor availability (high, medium, low). All woredas were assessed using this conceptual model, and 25 possible development domains were identified in Ethiopia.

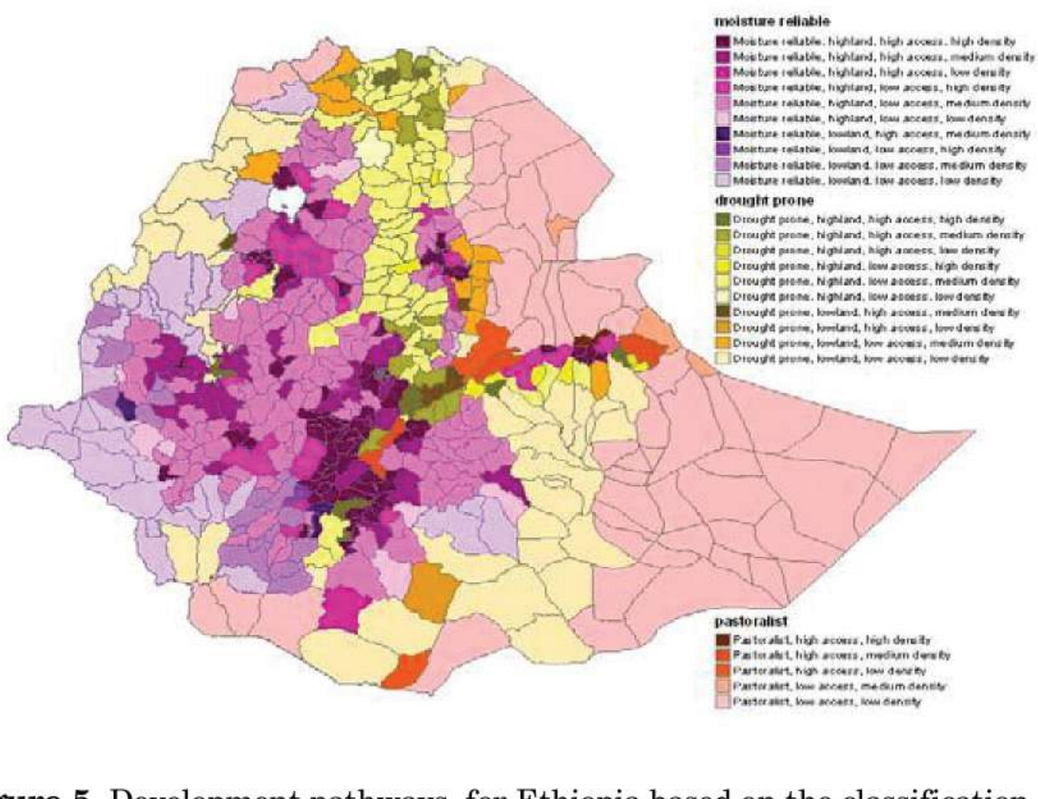

Figure 5. Development pathways for Ethiopia based on the classification

However, as agricultural potential is an abstraction of many factors, agricultural potential is not a uni-dimensional fixed concept. Still, it changes over time to change natural conditions (such as climate change) and human-induced conditions (such as land degradation). The multi-dimensional and dynamic nature of agricultural potential should be considered when developing more specific strategies of development. (Koomen et al., 2013).

Ethiopia is diverse in terms of altitude, climate soil types that have created a variety of agro-ecological and farming systems zones. Based on the length of the growing period and thermal conditions, 32 major agro-climatic zones have been identified (Elias, 2016). Depending on the potential for agricultural production, five major farming system zones can be placed in Ethiopia (Elias, 2010). These include the high potential perennial (HPP) zone comprising the coffee-livestock system of the south-western highlands, high potential cereal zone covering the north-central and south-eastern highlands, the low potential cereal (LPC) zones comprising north-eastern highlands and the rift valley, the low potential (poor soils, low rainfall, short LGP) but high market access areas (international corridors). This livestock zone comprises the pastoral and agro-pastoral lowlands, where livestock production forms the primary source of livelihood. The shifting cultivation zones of low population and high rainfall, high forest stand, and moist lowland areas are situated in the western and north-western parts (Figure 6).

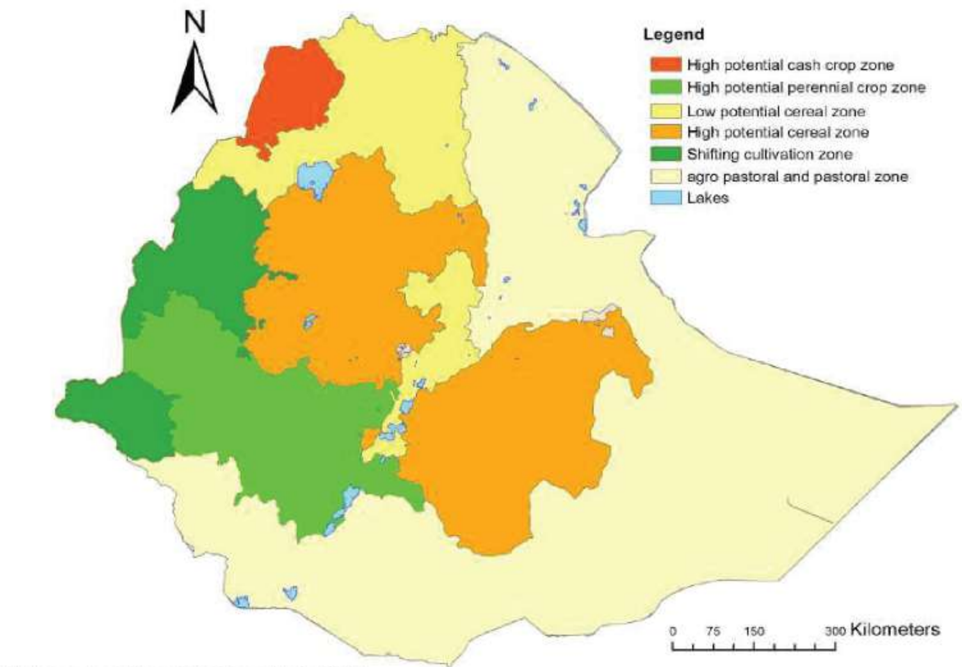

Figure 6. Agricultural potentials and farming system zonation in Ethiopia.

Access to markets is critical for determining the comparative advantage of a particular location, given its agricultural potential. For example, a community with an absolute advantage in producing perishable vegetables may have little or no comparative advantage (low profitability) in vegetable production if located far from urban markets. As with agricultural potential, market access is also a multi-dimensional and dynamic concept (distance to roads, condition of roads, distance to urban centers, degree of competition, access to transport facilities, etc.). Access to the market may change through investments in roads and communication.

Population pressure has long been acknowledged as being a major driving force regarding the labor intensity of agriculture (Boserup, 1965; Ruthenberg, 1980). Population pressure affects the labor intensity of agriculture by affecting the land/labor ratio and may also induce innovations in technology, markets, and institutions or investments in infrastructure. The settlement pattern in Ethiopia is such that areas of high agricultural potential (i.e., endowed with good soils and reliable rainfall) are more densely populated than the low potential disease-prone lowlands (Kruseman et al., 2006). The highlands with an altitude range of 1500-3500 m are characterized by humid and cooler climatic conditions and free from tsetse infestation and malaria problems, thus attracting immigration from less favored lowland areas. These factors have contributed to their high population densities accounting for 88% of the human population, 75% of the livestock population, and 95% of the total cultivated land (Elias, 2010).

This can be used as a basis for validation/verification and scaling out/up the available best practices to halt soil salinization/sodification suitable for the development domains. A central hypothesis of the development pathways approach is that the opportunities and constraints for sustainable development depend upon the comparative advantages in a particular location. Many factors may determine the comparative advantage of development pathways in different areas.

Studies on recommendation domains identify three dimensions in defining development pathways (Pender et al., 1999; Chamberlin et al., 2006). These are: (1) the agricultural potential of the area, which is a function of the bio-physical environment such as rainfall, soil quality, length of the growing period, and other topographic and agro-climatic factors; (2) market access – distance to markets and travel time to urban centers for market and information exchange (to purchase inputs and sell products); and (3) population density that determines labor availability (land/labor ratios) for agricultural intensification.

Agricultural potential is an abstraction of many factors that in uence the absolute (as opposed to comparative) advantage of producing agricultural commodities in a particular place. The biophysical factors include altitude and climate (i.e., mainly rainfall, temperature, and length of the growing period), soil quality (i.e., fertility, organic matter content, soil pH, rooting depth, etc.), presence of pests and diseases, among others. The socio-economic dimensions that define agricultural potential and development pathways are market access and population density, which determines labor availability (i.e., land/labor ratios) for agricultural intensification (Pender et al., 1999; Chamberlin et al., 2006).

6.2.3 Evaluate best practices for different recommendation domains

As implied in the best practice definition above, a best practice is best for a given set of biophysical (soil conditions, agro-ecology, land use, etc.) and socio-economic (market, labor supply, etc.) conditions. Using Participatory Rapid Assessment (PRA) tools, testing and validation of promising technologies involving researchers, extension workers, and farmers should be conducted through the participatory diagnostic process. The effectiveness of current best practices should be evaluated against set indicators as a pre-condition for scaling up/out of best practices. The validation/verification process provides evidence to determine under which biophysical and socio-economic circumstances a method functions as expected. Therefore, the nationally harvested best practices are required to pass through the validation process by the research system and development partners.

Regarding the biosaline approach of remediation of salt-affected soils, we assume that the ICBA-RAMSAP project has already implemented this step with the national and woreda stakeholders, including EIAR and the woreda office of agricultural extension. Through a bottom-up planning process, RAMSAP tested and validated a number of promising salt-tolerant fodder species such as Chloris gayana, Coloured Guinea (Panicum coloratum), Sudan grass, and crops (barley, quinoa, sorghum) in target sites. We now know the conditions in which these best practices can be scaled out/up, reaching more farmers and geographical areas.

6.2.4. Preparation of best practices manuals

Developing a technological package consisting of best practices should be the essential first step outlining the conditions for successful implementation and ensuring its wide-scale adoption in different recommendation domains. Best practice manuals should be prepared for each of the components. The package should be based on field-tested best practices and demonstrated evidence under farmers' conditions, such as the biosaline technologies tested by the ICBA-RAMSAP project in target areas.

The experience of the CASCAPE project may be helpful here. Based on field validation in different agro-ecological zones and farming system settings, the CASCAPE project has prepared 65 agricultural best practice manuals that have been handed over to the extension directorate of the MoA. As stipulated in the best practice manual, several of them have already been incorporated into the national extension package for wider application in suitable agro-ecological zones. Sharing this experience for scaling in the salt-affected lowlands can be vital in the scaling process for the bioremediation approach

Institutionalizing the best practices into the national and regional extension package and woreda development plan is an example of vertical scaling of innovation. Based on CASCAPE's experience, continuous engagement with policymakers at different levels – woreda, zone, region, and national – made it possible to incorporate some of the validated best practices into the government plans and strategies. The extension directorate has now formulated new extension packages for model farmers to grow maize, wheat, potato, soybean, faba bean, malt barley, and garlic commercially based on the CASCAPE best practice validated in the Ethiopian highlands.

6.2.5. Prepare extension training materials in local languages

There are often language barriers for extension advisors, subject matter specialists (SMSs), and DAs to understand the best practice manual and innovation guidelines written in English due to their limited knowledge of technical/agronomical jargon. For this reason, it may be necessary to translate best practice manuals into local languages. In addition, appropriate media of communication and language must be selected for the training sessions and best-fit practice briefing workshops. Furthermore, we learned that linear transfer of technologies does not always work, as seen with maize and malt barley in the southern region. Different materials targeting different groups should be considered.

6.2.6. Capacity development for woreda experts, DAs, and farmers

Diagnostic studies in the target areas have shown that lack of awareness and knowledge about the saline/sodic soils among the local communities and the managers, supervisors, and the irrigation crew of the irrigated farms has failed to implement the available solutions. Due to the lack of farmer skills in irrigation water management, salinity problems are worsening. For instance, due to poor land leveling and use of   ooding irrigation, water use efficiency is only about 35% in many areas. Uneven water distribution due to poor land leveling produces low and high infiltration rates, making low and high salinity patches within the same field. Therefore, comprehensive training of extension staff and farmers will be required to implement best practices and technologies available to rehabilitate saline/sodic soils.

Therefore, extension officers, development agents, and farmers should be fully trained in all aspects of crop tolerance and production (soil, water, climate, and crop management) under saline conditions. The training should include field assessment of saline/sodic soils and reclamation methodologies, including drainage, crop production technologies, and management. Therefore training of irrigation technicians and the staff of the MoWIE on water quality management is crucial to control the diversion of the saline Beseka water into the Awash River.

The training of trainers (TOTs) may be given to the woreda SMSs who then train the DAs at kebele level, and then the DAs train farmers at the FTCs. Different training modules and facilitators' guidelines and manuals should be prepared in the appropriate language for each training group. The idea is that stakeholders can prepare training guidelines and simplified extension messages on different aspects of soil salinity and irrigation water quality management. The preparation of guidelines and manuals for training different target groups (SMSs, DAs, farmers) requires combined efforts by the MoA and MoWIE. One of the major bottlenecks in irrigation water quality management is the lack of awareness and knowledge of technicians of the hydrology and water quality directorate of MoWIE. The key informant interviews show that the experts had limited experience in mixing ratios, irrigation amounts, frequencies, and cultural practices (e.g., land leveling, minimum tillage, crop residue mulching, etc.) that help avoid salt accumulation in the root zone.

For farmers, an effective means of skills training and capacity building is using the FTCs by encouraging information exchange and knowledge sharing among fellow farmers. This can be further enhanced by adopting the farmers' research and extension groups (FREGs) widely used in the AGP/CASCAPE projects. Although the FAO promotes the farmers' field schools (FFS), the FREG widely experiments in the Ethiopian agricultural research and extension system.

6.2.7. Awareness creation among policymakers

As indicated in the guiding principles of planning strategies, it is essential to link the field demonstrated evidence to policy at regional and national levels. Policymakers lack awareness of the extent, cause, and impact of salinization/sodification in Ethiopian agriculture. This is evidenced in the lack of an elaborated institutional strategy and priorities specific to Ethiopia's rehabilitation of salt-affected soils. A fundamental policy misunderstanding seems to exist in terms of land management under pastoral production systems. High-level policy engagement and awareness creation on the problem of salt-affected soils is essential to encourage the formulation of realistic and favorable land and water management policies in the irrigated areas. This goal can be achieved by opening a dialogue with policymakers to improve their understanding of the problem and its future implications. The management options for salt-prone land and water resources built on the accumulated wisdom of relevant stakeholders will assist in adopting these crops by communities. Policy engagement by pastoral communities residing in the salt-affected soil has been weak partly due to a lack of field-based empirical evidence on the problem of salinization/sodification. Field investigation generates essential empirical evidence that would form the basis for engagement with policymakers to formulate favorable policies that would address land degradation from salt accumulation.

In this regard, the experiences and results obtained by the ICBA-RAMSAP project are essential to be shared with policymakers at regional and national levels. These results can be helpful to take a more proactive policy lobbying and advocacy work to address the general land degradation and salinization of irrigated lowland agriculture. Proper understanding of the ecology of the traditional pastoral production system and the complex customary arrangements for resource management is necessary to formulate appropriate land policies that can halt ever-increasing soil salinization.

Some strategic action points for effective policy engagement may include (1) organizing high-level policy field excursion for MoA and regional BoA officials to observe and learn on their own. Engaging members of the agricultural standing committees of the Parliament to visit the performance of selected best practices in the target areas in the high potential highlands can be instrumental in in uencing the policymakers. These interactions can be helpful: (1) to channel information and lobby for policy change; (2) organize a workshop to share the results of field trials/demonstrations actively; (3) create research-extension platforms for continuous dialogue and discussion on the demonstrated field evidence in ameliorating salt-affected soils; (4) preparing policy briefs targeting high-level officials.

6.2.8. Incentives for farmers and enabling environment for DAs

A conducive enabling environment is an essential factor in scaling. Without appropriate incentives, innovation would be hampered, and the process of scaling-up would not be successful. Scaling up operations needs to include incentives for the key actors, mainly farmers and DAs. The scaling process and uptake by farmers may consist of different elements such as building effective extension systems; policy reforms on input/output pricing; expanding access to credit and financing; accounting for social, cultural, and political realities on the ground; and building local cooperation and partnerships.

Due to limited economic benefit, farmers (agro-pastoralists) are less interested in adopting best practices. Access to institutional credit is critical because it increases the probability of farmers adopting innovations. An adoption study in the Ethiopian highlands revealed that access to institutional and financial support positively stimulates technology adoption by relaxing the liquidity constraint and boosting a household's risk-bearing ability (Tefera et al., 2016). A proper study on market pull and production push should provide information on whether market demand for certain commodities is expected to rise, resulting in increased commodity prices. If this is the case, farmers are more likely to be willing to invest in this commodity and related practices (Koomen et al., 2013). Cost/benefit analysis, including criteria set by farmers, should reveal for different farming households to what extent initial investments will lead to higher returns. The innovation should be adapted so that this is the case; otherwise, farmers cannot invest in the technology/practice at stake.

Concerning scaling up the biosaline agriculture practices, it is essential to create market linkage for fodder-producing farmers to have economic benefits. As highlighted in earlier sections, there is a soaring market for hay in the beef and dairy sectors in major regional cities (e.g., Semera). Creating linkages between local communities, industry and traders is of utmost importance to exploit the full potential of the feed market. Local youth/agro-pastoral communities can go beyond backyard fodder production to hay production to supply to the booming beef and dairy farms. But first, it would be necessary to train them.

In Ethiopia, the DAs are the frontline extension advisers who play a critical role in technology dissemination and uptake by farmers. Despite the large-scale training of DAs, capacity at the FTC level is often weak. Further, DAs have a minimal incentive structure to stay in their positions and fully perform their role. These incentive issues related to salary levels, career progression opportunities (upgrading from Diploma to BSc), equipment, and resources prevent them from effectively carrying out their tasks and supervision and mentoring. Transportation is particular havoc in the rural settings, and DAs are expected to cover the whole kebele under their target. Simple transport arrangements such as motorbikes or even bicycles would help boost the morale of the frontline extension workers.

6.3. The CASCAPE experience in scaling agricultural best practices

Over the past ten years (2011-2020), the Dutch-sponsored CASCAPE project has supported the AGP and research system in validating and scaling up agricultural best practices in the high potential highlands. Through the integration of systems approach and bottom-up planning process, the project carried out a joint best practice validation program involving farmers, extension workers, university staff, and researchers from the RARIs. This testing and validation phase undertakes several consecutive and interrelated screening activities, including diagnostic studies (problem analysis using the PRA tools), participatory planning, testing options, and validation of best practice options. A national protocol has been developed for comparing the best practices against research recommendations and conventional approaches. Criteria were set for proof of best practices, including agronomic efficiency (productivity or crop yield advantage), economic profitability (marginal rate of return), and environmental sustainability (soil nutrient and organic matter enrichment), gender (no-harm effect to women and girls), nutrition (nutrient-dense crops), and farmers' preference (social acceptability). The validation protocol involving the three plot approach and the criteria of best practice/technology evaluation piloted by CASCAPE have now been incorporated in the research and extension system, including in the revised best practice scaling guideline of the MoA.

Based on the outcome validation trials, pre-extension demonstrations (PEDs) are carried out on large plots of land (minimum of half a hectare) involving CASCAPE researchers, extension workers, RARIs' staff, and farmers. The PEDs are meant to serve specific purposes, including (1) creating a platform for different actors (seed suppliers, extension workers, researchers) to have more awareness about the performance of the best practice/technology; (2) helping researchers to identify participant farmers in the target areas together with district and kebele level extension workers; (3) benefit participating farmers from accessing the technology (e.g., seed, training); and (4) train farmers and other stakeholders on the characteristics and management aspects of the new technology. For greater visibility of the new technologies, a minimum of a quarter of a hectare per participating farmer will be allotted. The demonstration will be based on a clustering scheme, for example, in crop and forage technologies, using FREGs.

The significant achievement of CASCAPE was generating best practice technologies that proved to more than double crop yields and capacity building for the uptake and institutionalization within the research and extension system. Comparing crop yields obtained from CASCAPE-PED trials across regions with data from the Central Statistical Agency (CSA) shows that the yields of cereals, potatoes, and legumes were more than double the average regional values. The yield advantage of CASCAPE-validated best practices compared to the average yield from local farmers' regular practices and regional and national average data obtained from CSA are summarized in Table 2.

Table 2. Yield advantage of CASCAPE-validated best practices compared to farmers' practices

Crop	Region	Yield (tha^{-1})			% yield over local	%yield over national
		CASCAPE	Local	National		
Wheat	Amhara, Oromia & SNNPR	4.9	2.6	2.8	88.46	75.00
Maize	Oromia and SNNPR	6.03	4.28	3.9	40.89	54.62
Potato	Amhara	37.05	18.77	14.67	97.39	152.6
Food barley	Amhara	2.6	1.8	1.97	44.44	31.98
Faba bean	South	2.10	1.45	1.93	44.83	8.808
Malt barley	South	4.25	2.20	1.93	93.18	120.2
Soybean	Oromia	2.56	1.74	2.31	47.13	10.82

6.4. Recommendations for scaling up in Ethiopia

Soil salinity-sodicity has become a growing cause of concern in Ethiopian lowlands, particularly in the middle and lower Awash basin. In contrast, there is a current surge of interest in expanding irrigated grain production in the lowlands targeting to irrigate 66,000 ha of land to meet Ethiopia's food needs. This, however, calls for sustainable utilization of vast tracts of potentially irrigable land (44 million ha) in the lowlands by adopting appropriate on-farm soil and water management practices.

Technologies and practices are well-known and readily available for the reclamation of saline/sodic soils. These may include (1) good on-farm soil management practices (minimum tillage and mulching to avoid compaction, proper seedbed preparation, and land leveling, etc.); (2) hydraulic measures such as use of good quality irrigation water and efficient irrigation methods (based on ETo crop requirement, avoid flooding/basin method) and adopting appropriate drainage systems; and (3) by implementing biosaline agriculture which involves the use of salt-tolerant crop and forage species. In Ethiopia, the MoSF has recommended hydraulic measures, including leaching, plastic, and clay pipe-based sub-surface drainage, sub-soiling methods for the heavy clay soils. However, these strategies proved less effective due to the increasing rise of groundwater levels resulting from the flooding/basin method of irrigation. Their adoption was limited due to high cost and technical complexity.

It is saddening to note that despite vast areas of salt-affected soils with a high possibility of spreading in the country, there is little or no standardized research, extension, and development strategies to alleviate the problem. Whereas the current extension strategy places a concrete work program for acid soil reclamation (based on liming) in the highlands, it provides no elaborated strategy/priorities for ameliorating saline/sodic soils. Although the revised soil and water research strategy of EIAR identifies salt-affected soils (saline/sodic soils) as "special problem soils", it does not provide any road map for the rehabilitation of salt-affected soils except proposing the application of gypsum. There are no research efforts to generate data/information on the quantity of gypsum to be applied or method and depth for incorporating/mixing it into the soil. We believe that this lack of research and extension intervention has exposed the already fragile lowland ecology to severe soil salinization/sodication.

The biosaline approach is most appropriate under the Ethiopian conditions because it allows effective and economically practical use of salt-affected lands for growing food and fodder crops that are most needed in the country. Some fodder species such as sesbania serve as bio drainage plants and are effective in lowering the groundwater table (via bio-pumping) for areas where high salinity and canal seepage have become problematic. The ICBA-RAMSAP project has introduced over 20 genotypes of different food crops (barley, quinoa, sorghum), forage grass (Rhodes grass, buffelgrass, Panicum, etc.), forage legumes (alfalfa), and shrubs/trees (sesbania) that are suitable for salt-affected lands. What remains to be done is to activate the extension service to scale these genotypes to more expansive areas where salt-affected soils are prevalent.

This study, therefore, placed particular emphasis on documenting the scalable experiences and providing steps and guidelines in scaling up and wide-scale implementation of the biosaline agricultural practice piloted by the ICBA-RAMSAP project. The step-by-step scaling strategies and sample documents of the CASCAPE project are well-elaborated. In this regard, launching the LLRP project for whom a key objective is to disseminate salt-tolerant crop and fodder species offers an excellent opportunity for pilot scaling of RAMSAP-validated biosaline approach in other areas where soil salinity is prevalent. We anticipate that the experiences of LLRP would provide a stepping stone for the directorate to formulate extension packages for saline soil management.

In addition, the report captures current strategies and gaps/challenges along with suggested solutions/recommendations and opportunities to scale up and wide-scale adoption of best practices to mitigate the spread of soil salinity. Challenges may be technological (relative performance, acceptability, simplicity, and replicability); socio-economical and institutional (e.g., input supply, market linkage, access to credit, etc.); political/policy related in nature such as secured rights to land and water, input/output price, and lack of awareness and knowledge of farmers and extension advisors. Many opportunities could harness scaling up efforts such as the presence of extension advisors at kebele level and lowland research stations, the growing demand for high-value agricultural products from the ever-increasing middle-class population, and the increase of innovative young farmers community.

Some of the recommendations for mitigating the identified challenges/gaps and harnessing the opportunities are discussed below:

- Avoid the use of saline water for irrigation. Diagnostic studies have shown that poor quality irrigation water having high levels of soluble salts has been widespread in the irrigated lowlands of Ethiopia. The problem is particularly severe in the lower Awash due to mixing the saline Lake Beseka water with the Awash River water. In this regard, the current practice of diverting the saline Beseka lake water to Awash River must stop.

- Efficient water management is essential. The inefficiency of irrigation is the single most important cause of soil salinity. Water application above crop and leaching requirements has contributed significantly to waterlogging, groundwater rise, and soil salinity. Hence, it is crucially important to avoid using saline water for irrigation, avoid flooding/basin method of irrigation, and adopt efficient irrigation methods (amount, frequency) based on ETo and crop requirement.

- Adoption of improved on-farm soil management practices, such as minimum tillage and mulching to avoid compaction, proper seedbed preparation, land leveling, and enhancing soil fertility by adding compost, farmyard manure, crop residue, etc.

- Producing qualified irrigation agronomists from A/TVETs and agricultural universities. This is suggested given the limited awareness among farmers, extension workers, and irrigation agronomists on salinity management options.

- Seed multiplications in research centers, FTCs, and on-farm fields to address the severe challenge of supplying good quality seed, particularly for most promising fodder grasses (Rhodes grass, Sudan grass) and legumes (alfalfa).

- Create increased awareness among policymakers to address some fundamental misunderstanding pastoral land use and land management systems. This problem can be addressed by organizing high-level policy excursions to visit field sites, meetings, and workshops to open dialogue with policymakers on empirical field results; producing and distributing policy briefs and technical papers based on in-depth thematic studies.

- Create increased inter-institutional collaboration in irrigation water and saline soil management. Various departments are mandated to control irrigation water quality and manage salt-affected soils structured under the MoWIE and MoA. However, there is little communication and coordination between ministries and even more worryingly between different directorates/departments of the same Ministry. Therefore, it is crucially important to establish a solid inter-institutional collaboration mechanism between appropriate units of MoWIE, MoA, EIAR, and RARIs for saline soil management and irrigation water quality inspection.

07 SEED DISTRIBUTION OF RECOMMENDED CROP GENOTYPES

7.1 Seed distribution in Ethiopia

Crop plants differ a great deal in their ability to survive under saline conditions. Information on the relative tolerance of crops to salinity is of critical importance to plan cropping schedules. There are situations where farmers must live with salinity problems, e.g., areas with saline irrigation water. In areas where good quality water is available for irrigation, crops can be grown with reclamation efforts to make reclamation economical. Studies done under the RAMSAP project showed promising results in salinity tolerance, biomass yield, and ameliorative effects for different forage and legume crops. As a result, genotypes of various crops have been recommended for scaling up to:

1. Promote economic utilization of salt-affected soils by growing salt-tolerant crops.
2. Increase awareness of the economic and agronomic benefits of salt-tolerant crops.
3. Improve and create access to livestock feed through the scaling up of improved forage crops.

For the scaling up of recommended genotypes of food and forage crops, seed multiplication units have been established in EIAR research stations and farmer fields in different regions. In the Werer research station, genotypes of three forage crops (Cowpea = 3; Lablab = 3; Rhodes grass = 3) and two food crops (Sorghum = 3; Barley = 2) were cultivated on 11 ha. The area under each crop is given in Table 3. These crops were harvested in April, producing 15 tons of seed for different crops.

Table 3. Seed multiplication at the Were Research Station in Amibara district

Crops	Uses	Area planted (ha)	Remark
Sorghum	Both (food and forage)	3.75	3 genotypes
Barley	Both (food and forage)	2.25	2 genotypes
Cowpea	Both (food and forage)	4.00	3 genotypes
Lablab	Only forage	0.5	3 genotypes
Rhodes	Only forage	0.5	3 genotypes
Total		11.00	

Based on the agronomic and economic efficiency, about 14 genotypes of five different crops were selected for scaling up in other areas. These include Sorghum, Barley, Cowpea, lablab, and three forages (i.e., Rhodes grass, Panicum, and Cinchrus grasses). These recommended genotypes have shown superior performance than the existing local crop varieties in production potential, nutritious values, and increased economic returns under salt-affected conditions. For these reasons, farmers in the four regions (Afar, Amara, Oromia, and Tigray) have shown great interest in these crops and forage varieties. From these seed multiplication units, more than 15 tons of seed of different crop genotypes were produced. About 500 grams of seed was given to each farmer for testing and further multiplication. The seed selection to be given to farmers was made based on the area, farmers' interest, and seed availability. Since the demand for seed was high compared to the availability, a strategy was developed. This includes that each farmer who will get seed from the project was bound to provide seed to at least five of their neighboring farmers after the harvest. These farmers can then grow and multiply their seed. Some farmers with relatively larger landholdings offer to produce seed and share with their neighboring farmers. Seeds of different crops were provided free of cost. The extension workers trained by the project extended advisory services to these farmers about the planting and caring of these seeds.

Besides, seed multiplication units were established in different regions. Seed multiplication activities were also carried out on farmer fields, and more than 2.5 tons of seed were obtained from these fields (Table 4). Most of this seed was kept by farmers for the next season, and the remaining was distributed to 100 neighboring farmers. Therefore, this seed was not used for distribution outside the project areas.

Table 4. Seed multiplication and demonstration at farmer fields in different regions.

No.	Regions	District	Crops	Area (m^2)	No. of Farmers	Harvested seed (kg)
1	Oromia	kombolcha	Rhodes	9850	2	320
			Panicum	883	1	300
			Lablab	1020	2	154
			Alfalfa	1000	1	158
		Sebeta	Rhodes	2500	2	188
			Panicum	1000	2	124
			Panicum	1000	1	230
		Awas	Lablab	2500	2	250
2	Amhara	Raya Kobo	Rhodes	3000	2	180
			Panicum	2500	2	30
3	Tigray	H/wejerat	Panicum	7500	4	86
			Rhodes	5000	2	192
4	Afar	Amibara	Rhodes	5000	1	195
			Panicum	12500	1 1	98
			Total	**5.5 ha**	**26**	**2,505**

Seed multiplication at farmer fields

7.2. Scaling up strategy (seed distribution)

Interested farmers from selected woreda of different regions were chosen to work with the extension workers to scale up the recommended seed. Each farmer was given the seed required to cultivate a 100 m2 area. This area size was preferred because most farmers were smallholders, and they could not afford to allocate more land to test a new crop variety. From each of the six districts (Table 5), 50 woredas were selected. From each woreda, about 100 farmers were selected. This way, we were able to reach 30,000 farmers.

Table 5. Strategy for scaling up recommended food and feed crop seeds.

Activities	Type of seeds	Name of districts	No. of farmers	Remarks
Scaling up forage, legume crops	Rhodes grass, Lablab, Panicum, Cowpea, Barley Sorghum, Quinoa,	Amibara, Kobo, Hintalo wajirat, Alamata, Adamitulu, Ziwaye dugda	30,000	Already seed is distributed to 5000 farmers. More will be distributed after the on-going seed multiplication.

Before the large-scale distribution of seeds, special training are organized for extension workers to apprise them about different agronomic and physiological parameters of these crops. They are educated about appropriate sowing and harvesting times, soil, and water quality requirements, fertilizer, pest management issues, and safe storage of the produced seed.


7.3 Seed distribution in South Sudan

In South Sudan, agriculture accounts for 36% of the non-oil GDP. Approximately 80% of the population living in rural areas is mainly dependent on subsistence farming, and 75% of the households consume cereals as a central part of their daily diet. Despite abundant water supplies, only 5% of the total 30 million ha arable land is cultivated. Crop yields are meager, which negatively affects the incomes and livelihood of poor farmers. Significant barriers are lack of agricultural inputs such as seed and fertilizer, poor advisory services, and inefficient irrigation management. Although South Sudan has the highest livestock per capita globally, with 23 million head of cattle, sheep, and goats, there is little use of improved seed varieties or breeds of livestock. There is a strong need for improved forage varieties resistant to common diseases to enhance livestock productivity.

The project's main focus in South Sudan was to provide seed of improved food and fodder crops to help develop the livestock sector and ensure food security during the dry period. Since more than 70% of the population consumes cereals as the primary food, we introduced cereals that can grow in dry and hot environments with less water. Many of these crops, such as Sorghum and Pearl Millet, could also be used as fodder. The field trials indicate that the fresh biomass production of these crops is much higher than the local varieties. Therefore, farmers showed great interest in these crops.

The salt-affected lands in South Sudan are in the White Nile irrigation schemes. These areas have hardly been utilized for agricultural production despite having great potential due to freshwater availability from the Nile. Therefore, bringing these degraded lands to acceptable production levels is essential to ensure food security and social stability.

Based on the baseline survey conducted during 2016-18 under the RAMSAP project in South Sudan, we interviewed about 400 farmers from ten different locations in the country (Juba, Kapoeta, Torit, Yambio, Wau, Aweil, Rumbek, Bor, Renk, and Terekeka). One of the touching outcomes of the analyzed data shows that 23.5% of the seeds cultivated by the farmers are from their savings, NGOs supply 13.5%, 62.5% are purchased from the market, and 0.5% from government aids. Low crop yields were reported due to poor germination of the seeds. Poor seed germination was due to the following:

- Lack of productive varietal testing, introduction, and development research.
- Inadequate crop varietal maintenance.
- Absence of local seed, thus foundation seeds of certified and/or commercial seed production.
- Lack of well-planned seed production, i.e., multiplication of seed up to the quantities needed,
- Lack of seed conditioning. Farmers' traditional seed saving methods handled the quantities of seed produced in a seed program. These damages stored seed. Therefore, seed threshing, drying, cleaning, treating, packaging, and storage facilities are required.
- Lack of proper seed marketing and distribution. Seed have value only to the extent they are distributed to farmers and planted by them. Marketing, therefore, involves the promotion of the seed produced so that farmers demand it. The distribution consists of the management and mechanics of arranging the seed desired by farmers at the proper time and place.
- Lack of quality assurance and control. The quality of the seed is crucial. Therefore, a system is needed to assure and control the quality of the seed produced and marketed. Seed certification, seed testing, seed legislation are mechanisms for ensuring and maintaining the quality of grain.

In the RAMSAP project, we undertook some activities to overcome the challenges before the upscaling could start. The primary focus was training the field staff on seed production, harvesting, and storage to maintain their health. The training was conducted in all the selected seed multiplication sites and where scaling up would be implemented. In many areas, farmers also attended training and shared their opinion about the scaling-up program. These include the following.

1. Establishment of field trials for imported and local varieties of cereals and legumes crops
2. Management of seed multiplication sides
3. Training of field supervisors on crop diseases and management, crop harvesting, and post-harvesting techniques to reduce losses
4. Training on the marketing of agricultural products
5. Training on field crop data collection and management
6. Training on land preparation, establishing, and planting
7. Training on storage of farm products
8. Training on seed packaging and storage
9. Training on management of covid19 impact on agricultural productivity

Scaling up resilient non-traditional crops to selected farmer groups in the project area was meant to be part of seed security. This would enable the sustainable capacity for farmers to have enough seeds from the different crops at the right agriculture calendar timing in all the different levels such as family, community, agro-ecological zone, or food economy zone. Interaction with the farmer groups indicated that although there is a local seed market, a seed may also be acquired inside communities and other neighboring communities. The seed market has no certified seed of improved varieties. The market is affected by the free seed distribution by Non-Governmental Organizations (NGOs) and governmental institutions. Because most of those NGOs import the seeds from neighboring countries, there is a risk of mixing, poor storage, and transport. Therefore, the scaling-up is the best option to reach many potential farmer groups/ individual progressive commercial farmers.

As per RAMSAP project protocol, South Sudan should reach 20,000 farmers during the project. The project activities were implemented in the ten most potential agricultural sites in the country. At each of the ten RAMSAP project sites in South Sudan, ten villages were selected and from each town. Around 250 farmers were targeted for seed distribution (10*250*8 = 20,000). This way, we reached 20,000 farmers. Among others, crop variation was critically important for these locations. Therefore, in this upscaling program, we focused on six types of crops for each site. The beneficiaries include farmers from the rural areas (Individuals and groups), government institutions (ministries, universities, and high schools), private agricultural companies, and Agricultural NGOs.

Subsistent farmers dominate South Sudan; thus, to reach out to 20,000 farmers, the ICBA team packaged the different seeds in small packs of 750g each. About 16 tons of seed was produced through seed multiplication activities, distributed to more than 21,000 farmers at various locations in South Sudan (Table 6). The packing materials were prepared by preparing envelopes and then placing printed labels showing seed type, variety, and quantity. After the seed packing activities, seeds were distributed to targeted locations through air plans and vehicles depending on the distance.

See packing in South Sudan

Various approaches were used to cover the targeted groups in South Sudan. These include cultivation using seeds from seed multiplication fields, locally available or imported from ICBA. Other approaches include extension work, i.e., farmer field schools and organizing field days at the selected demonstration farms to train farmers in optimal production practices. The trainers were the technical members of the RAMSAP project, technicians from the MoA, and food security at the state level for direct monitoring and supervision. The collaboration with some local partners was also considered.

A comprehensive scaling strategy was developed in the second approach, targeting crop production and consumption across South Sudan. Due to variation in food types in different parts of the country, five crops (Sorghum, Barley, pearl millet, Quinoa, and cowpea) were distributed. All the activities used in the upscaling program build a good understanding of seed's primitive and catalytic roles in crop agriculture, which is essential for formulating effective agricultural and rural development strategies. Farmers are now aware that seeds are required in relatively small quantities, multiplied rather than consumed in the production process, familiar to all cultivars. On the other hand, farmers are now aware that seed has two disadvantages often overlooked compared to other inputs. They are alive and must be maintained in a living condition to fulfill their propagative function, and the seed production has to be planned well in advance. They should be used on time and should not be kept for long.

Before the scaling up, the following field activities were carried out.:

- Seed labeling
- Seed weighing and seed packaging
- Seed chick list and allocation

Several meetings were organized with the farmer representatives, government officials, and other concerned authorities to distribute seeds among potential selected farmers. These include

1. Meetings with Directors and field supervisors at state levels
2. Interview with farmers' representatives on the seed.
3. Seed distribution.
4. On-Farm training on/ each location:
5. Importance of seed selections, management, and proper field operations
6. Selection of appropriate locations for better water management
7. Encourage farmers to produce more food to overcome food shortages.
8. Prepared farmers' fields for seed upscaling.

Training workshop before seed distribution in South Sudan

Quality improved seeds from various varieties ranging from cereals (Sorghum, pearl millet), legumes (cowpea), and grasses (Chlorosis Guyana, Sesbania). Packaging envelopes weighing half a kilogram each were prepared with labels indicating the name of the variety, the seeds' weight, production season, agronomic practices (spacing, number of seeds/ hole, depth of planting, etc.). To avoid contamination, the different crop seeds were weighed using a balance scale and packed and sealed in the envelopes.

See distribution at different locations in South Sudan

Table 6. Distribution of seed and number of beneficiary farmers in different locations

Site	Crops	Quantity (kg)	Farmers	Site	Crops	Quantity (kg)	Farmers
Juba	Sorghum	650	900	**Yei**	Sorghum	650	900
	Peal Millet	450	600		Peal Millet	450	600
	Maize	450	600		Maize	450	600
	Cowpea	450	600		Cowpea	450	600
	Total	**2,000**	**2,700**		**Total**	**2,000**	**2,700**
Torit	Sorghum	650	900	**Renk**	Sorghum	650	900
	Peal Millet	450	600		Peal Millet	450	600
	Maize	450	600		Maize	450	600
	Cowpea	450	600		Cowpea	450	600
	Total	**2,000**	**2,700**		**Total**	**2,000**	**2,700**
Kapoeta	Sorghum	650	900	**Yambio**	Sorghum	650	900
	Peal Millet	450	600		Peal Millet	450	600
	Maize	450	600		Maize	450	600
	Cowpea	450	600		Cowpea	450	600
	Total	**2,000**	**2,700**		**Total**	**2,000**	**2,700**
Aweil	Sorghum	650	900	**Wau**	Sorghum	650	900
	Peal Millet	450	600		Peal Millet	450	600
	Maize	450	600		Maize	450	600
	Cowpea	450	600		Cowpea	450	600
	Total	**2,000**	**2,700**		**Total**	**2,000**	**2,700**
	All Total	**8,000**	**10,800**			**8,000**	**10,800**

7.4. Farmers' responses on seed distribution

The farmers of both countries gave their recommendations for seed distribution. These include:

High-level support: A proper plan within the government system that links the national government with state authorities is essential to meet the need and determination within the decision-making levels. The ministry must establish a standard seed development policy to ensure stability in the seed development program. This policy must prioritize the agricultural sector's total development, not only for seed, research, and extension. In the absence of such high-level support to assure a sustainable supply of personnel, finance, and land, a seed program cannot develop beyond its current level.

Productive plant research program: The cornerstone of a practical plant breeding, introduction, and varietal testing program is a seed program/industry. Organizing a seed program on local or unimproved varieties can rarely be justified. Improved seed production and processing practices might result from sporadic yield increases, but it has a negative long-term effect. History has proved that farmers have worked out practical approaches for saving seeds of self-pollinated varieties over hundreds of years. Most farmers require only a small quantity of seed, for their plantings. They always rely on one type of seed until a better variety is introduced at the farm level. Due to the absence of sustainable funding in South Sudan, these associated activities are not suitable.

Cultivator demand: Introducing a new variety is the most challenging task encountered in developing a seed program. Therefore in our ongoing seed distribution activity, we are creating awareness among the cultivators of ICBA imported and local varieties from various South Sudan locations to use crop varieties that produce a higher yield. This activity's outcomes will be judged by the end of the season by getting farmers' feedback and perception.

Sound plan and organized effort: Planning and management are the most in uential driving forces of the seed program. So far, RAMSAP-South Sudan has a well-developed strategy for seed upscaling. The Ministry of Agriculture and Food Security, in collaboration with ICBA, takes the lead in the ongoing program. Good coordination between the national and state ministries is needed to ensure proper monitoring and supervision of the distributing, planting, and seed management. We understand that there is no formula for seed program success because its biological characteristics impose limitations. Aside from these limitations, we managed to provide a plan and organization that will foster maximum effectiveness and efficiency and encourage farmers, private persons, and institutions to become contract seed producers and other private persons and institutions.

A crew of trained personnel: Three components must be considered for seed production activities. These include seed production, processing, and storage. As per RAMSAP scheduled activities, we are at the production level, and the other remaining activities are theoretically implemented through training and workshops. Therefore, we are working with the farmers to implement the practical exercises. For the implementation of these activities, trained staff is the prerequisite.

In summary, under the RAMSAP project, the seed of alternative crops was distributed to more than 50,000 farmers in Ethiopia and South Sudan. These farmers will be further distributing seeds to their fellow farmers. The seed was mainly distributed to smallholder farmers, and it is hoped that it will benefit more than 100,000 ha of salt-affected lands in both countries. Through this strategy, the improved seed of alternate crops will reach a significant number of farmers. The cultivation of this seed will help improve the productivity of salt-affected lands, improve farm incomes, and enhance the livelihood of smallholder farmers. Farmers have shown great satisfaction and interest in these seeds for the rehabilitation of their salt-affected soils.

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BRIEF ABOUT THE RAMSAP PROJECT

Background

Increasing salinity remains a challenge to the sustainability of irrigated agriculture in Ethiopia and South Sudan as it reduces natural biodiversity and farm and livestock productivity. The agricultural sector in Ethiopia supports 85% of the workforce. About 85% of the population living in rural areas is directly dependent on agriculture for their livelihood. Seven million smallholder farmers produce more than 95% of the total agricultural outputs, including food crops, cereals, oilseeds, and pulses. Cotton and sugar are grown in state-owned large-scale enterprises. Ethiopia also has enormous livestock resources, including cattle, sheep, goats, and camels. Despite high biodiversity and distinctive ecosystems, food shortages are widespread, and since 1970 there have been severe famines almost once per decade.

Land degradation is considered one of the major causes of low and, in many places, declining agricultural productivity and continuing food insecurity, and rural poverty in Ethiopia. Today, Ethiopia stands first in Africa in salt-affected soils due to human-induced and natural causes. Currently, about 11 million ha (Mha) land in Ethiopia is exposed to salinity and sodicity, out of which 8 Mha have combined salinity and alkalinity problems. In contrast, the rest 3 Mha have alkalinity problems. About 9% of the population lives in salt-affected areas. The saline areas in Ethiopia are in the Awash River basin, and the situation is expected to exacerbate due to climate change-induced factors. There is an urgent need for salt-affected soils to be restored to their production potential to produce enough food for the rising population.

In South Sudan, agriculture accounts for 36% of the non-oil GDP, with 80% of the population living in rural areas largely dependent on subsistence farming and 75% of the households consuming cereals as a prominent part of their daily diet. Despite abundant water supplies, only 5% of the total 30 Mha arable land is cultivated. Crop yields are low, which negatively affects the and livelihood of poor farmers. Significant barriers are lack of agricultural inputs such as seed and fertilizer, poor advisory services, and inefficient irrigation practices. Although South Sudan has the highest livestock per capita globally, with 23 million cattle heads, there is little use of improved seed or breeds of livestock. For increased livestock productivity, there is a need to introduce improved forage varieties resistant to common diseases. The salt-affected lands in South Sudan are in the White Nile irrigation schemes. These areas have not been utilized for agricultural production despite availability of freshwater from the Nile. Therefore, bringing degraded lands to production is essential to ensure food security and social stability.

With a 3% average population growth in these countries, future food security and the livelihood source for a considerable portion of the population remains a challenge to the governments. Increasing the productivity of existing salt-affected lands and protecting newly developed areas from the spread of salinity is therefore of paramount importance. The smallholder farmers in both countries can increase their agricultural productivity and farm incomes if their technical and financial capacity is enhanced. They need guidance on the improved irrigation and salinity management strategies and access to modified salinity-tolerant seeds for crops and forages. Therefore, for millions of farm families in these countries, access to inputs will be a dividing line between poverty and well-being.

The areas of low to moderate salinity levels can be restored by improving irrigation and crop management practices. However, in areas where increased salinity levels have restricted the growth of normal field crops, use of Biosaline Approach could be a potential solution. This approach is based on adaptable technology packages of salt-tolerant fodders and halophytes integrated with livestock and appropriate management systems. These integrated crop-forage-livestock feeding systems can increase resilience of smallholder farmers who are largely dependent on the livestock sector.

This project will devise a strategy to improve the productivity of saline soils to an economically feasible level and minimize future salinity development in these areas. The project will draw on past work's experiences to identify the most productive alternative crop and forage production systems and devise a strategy for scaling up these production packages to improve livelihood of rural communities, especially women in the target areas of both countries. Through enhanced crop yields and reduced land degradation, the project will improve farmers' resilience, thereby reducing migration to cities and health problems due to stress on families suffering from the impact of salinity on their livelihoods.

Project Goals and Objectives

The project's overall goal is to attain higher agricultural productivity, food security and income for smallholder farmers, agropastoral/pastoral communities through rehabilitation and sustainable management of irrigated salt-affected farming areas of Ethiopia and South Sudan. The main objective of this project is to introduce and promote appropriate technologies and practices for rehabilitation and management of salt-affected lands in Ethiopia and South Sudan and draw lessons for scaling up.

The Target Group

The project will directly target 5,000 smallholder farmers in selected areas in Ethiopia and South Sudan who face high food insecurity due to their high dependency on marginal water and land resources. The indirect beneficiaries will be about 50,000 farmers (40,000 farmers in Ethiopia and 10,000 farmers in South Sudan) dependent on forage production in both countries with an estimated total area of about 200,000 ha (150,000 ha in Ethiopia and 50,000 in South Sudan). These targets will be achieved by producing and distributing tested crop and forage seeds, disseminating improved soil and water management practices, and training farmers and extension workers in the target areas.

The rehabilitation of degraded lands will improve the livelihood of 9% of the population of Ethiopia which lives in salt-affected areas. In South Sudan, 7% of 30 Mha of land is being cultivated, rehabilitation and management strategies developed under this project will open a window of opportunity for thousands of rural farmers to improve the productivity of their degraded lands and increase their farm incomes. The outcomes of this project will significantly benefit women as they will have better access to food and health facilities. The transformation of degraded lands into productive lands will also create direct and indirect job opportunities for the large young population. This will help in reducing the migration trends of unemployed youth from rural areas to urban areas.

The project will target Ethiopian highlands (Tigray, Amhara, and Afar) and lowlands (Omara and Somali), which produce 87% of cattle and 5% of its sheep and goats; however, land degradation has reduced farm and livestock productivity of these areas resulting in rural poverty. The developed crop-livestock value chain system will benefit Ethiopia because this is the largest livestock producer in Africa. The project will target the White Nile irrigation schemes (50,000 ha area) in South Sudan. These soils have an immense potential due to the availability of fresh water from the White Nile River and its tributaries which runs through 7 out of 10 states, providing access to water supply and river transport access for agriculture producers. However, these soils are not being cultivated for decades due to low soil fertility and the non-availability of good quality seeds for crops and forages. Currently, 18% of the land is not cultivated because of seed shortage, and 9% is due to low soil fertility. Increasing the productivity of these lands will be crucial to ensure food security for the smallholder farmers of the area.

Strategy, Approach and Methodology

This project will adopt an integrated soil and water management approach to tackle the salinity problems in irrigated areas of both countries. The project strategy would be first to diagnose the issues and then develop long-term mitigation, management, and rehabilitation strategies at the farm and regional level relevant to the problem using proven and high-level international salinity science and management. Since the rehabilitation of saline soils through engineering or chemical amendments is an expensive and time-consuming process, this project will work on adaptive and mitigation methods to rehabilitate these soils.

This project will adopt a participatory approach to conduct field trials in different parts of both countries to test the suitability of local and imported crop and forage species to rehabilitate salt-affected soils. Adaptation trials will be conducted at the Farmers Training Centers (FTCs) and volunteer farmers' plots in collaboration with the national partners. These trials will also be used for demonstration purposes before scaling up. The project team will jointly implement the best management practices for salinity control at the farm level. Smallholder farmers (especially women and young farmers) will be trained to establish seed/gene banks at the community level. ICBA has successfully applied this approach in SSA.

The project will generate and disseminate sustainable integrated crop-livestock technology packages to diversify farmers' incomes through the sale of animal products and forages to local markets, thus making the production systems economically sustainable. However, salt-tolerant forage plants are variable in biomass production and nutritional value. The available salt-tolerant forages have not been selected or managed for improved livestock production. For this reason, they need to be tested locally for their (a) edible biomass production; (b) nutritional value (i.e., the response in animal production per unit of voluntary feeding intake), and (c) the use of micronutrients and nutraceutical properties.

The project will address gender equality and social issues as cross-cutting themes in each area. The project will include the most vulnerable groups of the society to ensure that the interventions benefit poor farmers and households. Since rural women play a crucial role in agricultural and livestock activities, enhancing their knowledge and capacity will be one of the main targets of this project.

Project Outcomes and Impacts

The immediate outcome will be the full implementation of new salt-affected management strategies within the pilot sites with related benefits to farming communities and land management organizations. The long-term effect will be new thinking and awareness about the new salinity management approaches and implementation of overall system reform. This, in turn, will lead to out-scaling of production packages beyond the project area through project partners, including key government organizations. The successful implementation of the above activities will increase the productivity of salt-affected lands, which will positively contribute to the country's economy and reduce rural poverty. The overall impact of the project will be revitalized agriculture in Ethiopia and South Sudan.

Scaling up Pathways

The critical element of this project is to pilot innovative strategies and approaches for the rehabilitation and management of salt-affected soils and then "scale up' recommended technologies to reach up to a more significant number of rural poor. All activities of this project will be carried out with the involvement of local rural communities. Once convinced, these communities will act as the champions of change and critical drivers in the process of scaling up. For successful scaling up, policy support and institutional infrastructure is very crucial. Opportunities and constraints that may affect the scaling up process will be critically evaluated during the pilot stage. For long-term sustainability, the overall impact of the alternative production systems on the lives of the rural poor, natural resources and environment will be reviewed.

Socio-Economic and Environmental Impacts

The project will develop modified approaches to improve water management for salinity control and demonstrate best soil management practices for different salt-tolerant crops and forages. Adopting alternative crop and forage production systems will reduce the area lost to salinity degradation, bring income to farmers, and improve the livelihood of poor rural communities, especially women. The transformation of salt-affected lands into productive lands will also contribute directly to poverty reduction by increasing fuelwood, construction materials, wild foods, and medicinal plants.

ABOUT THE INTERNATIONAL CENTER FOR BIOSALINE AGRICULTURE (ICBA)

ICBA is a not-for-profit, international center of excellence for research and development in marginal environments. It was established in 1999 through the visionary leadership of the Islamic Development Bank (IDB), the Organization of Petroleum Exporting Countries (OPEC) Fund, the Arab Fund for Economic and Social Development (AFESD), and the Government of United Arab Emirates. Through the Ministry of Climate Change and Environment and the Environment Agency – Abu Dhabi extended the agreement with IDB in 2010 and increased their financial support to the Center.

ICBA initially focused on the problems of salinity and using saline water for irrigated agriculture. Over the last 15 years, ICBA has evolved into a world-class modern research facility with a team of international scientists conducting applied research to improve the well-being of poor farmers in marginal environments. In 2013, the Center developed a new strategic direction addressing the closely linked income, water, nutrition, and food security challenges. The new Strategy takes innovation as a core principle and identifies five innovations that form the core research agenda: assessment of natural resources; climate change adaptation, crop productivity, and diversification; aquaculture and bioenergy, and policy analysis. ICBA is working on several technology developments, including conventional and non-conventional water (such as saline, treated wastewater, industrial water, and seawater); water and land management technologies, remote sensing, and modeling for climate change adaptation.

ICBA is a unique institute with a clear mandate and capacity to work on rehabilitating salt-affected lands. ICBA is the custodian of the world's largest collections of genetic resources of crops and forages suitable for salt-affected lands with a proven capacity of seed development and seed multiplication for a variety of environments. In addition, ICBA's long history of working in Africa with local partners makes it fully qualified and eligible to lead this project.

The International Center for Biosaline Agriculture (ICBA) is implementing a 4-year project on the "Rehabilitation and management of salt-affected soils to improve agricultural productivity (RAMSAP)" in Ethiopia and South Sudan. The project is funded by the International Fund for Agricultural Development (IFAD) and is being implemented with the technical support of the Ministry of Agriculture (MoA), Ehiopia and the Directorate of Research and Training (DRT), South Sudan. The project is of great importance for both countries as it directly targets resource-poor smallholder farmers, especially women and children, who face high food insecurity due to their dependence on marginal soils. The project is introducing innovative soil and water management practices and salt-tolerant genotypes of food and forage crops that have the potential to grow in marginal areas. In addition, scientists, extension workers and farmers are being trained to improve their capacity for the management of marginal resources. Through improved crop yields and reduction of loss of land to degradation, the project empowers farmers by increasing their resilience against the impact of salinity on their livelihoods.

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