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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Exploring farmers' perception, knowledge, and management techniques of salt-affected soils to enhance rice production on small land holdings in Tanzania

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Abstract: Salt-affected soils among the key constraints to land productivity in irrigated rice schemes, posing a decline in grain yield. This study was conducted to explore the farmers' perception, knowledge, and management practices of salt-affected soils in selected rice irrigation schemes of the representative districts in Tanzania. Whereas salt-affected soils were perceived as one of the constraints in the studied irrigation schemes, the extent of coverage and the severity of the effect are rarely documented. Therefore, the primary hypothesis of this study is that salt-affected soils could have an effect on rice production across irrigation schemes; and that farmers differ in perception, knowledge, and coping mechanisms. The Participatory Rural Appraisal (PRA) approach was employed to explore the farmers' information from Mbarali, Iringa, Same, and Moshi districts, whereby 323 rice-growing farmers were interviewed using semi-structured questionnaires. Moreover, 120 farmers were involved in focus group discussions and 24 key informants. Our

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Omar, M. M is a researcher at the Tanzania Agricultural Research Institute (TARI), under the Ministry of Agriculture in Tanzania. Currently, he is a Ph.D. student in Soil Science and Land Management, based at the Department of Soil and Geological Sciences of the Sokoine University of Agriculture (SUA), Tanzania. His area of research is on "Characterization, Mapping and Developing a Management Tool for Salt-Affected Soils in Selected Major Rice-Growing Areas of Tanzania". This paper aimed to increase awareness of the existing information on salt-affected soils and document the available management options, especially for rice growing farmers, as an effort of improving grain yield and farmers' food security and income through small land-holdings. His broader research interests include soil inventory, land management, soil and water conservation, and agriculture climate-related challenges.

PUBLIC INTEREST STATEMENT

Food security for the apace growing population has become the main agenda in almost all developing countries due to environmental constraints and climate change that translate into poor agricultural food production. There is an increasing concern from rice farmers, especially in irrigation schemes on the decline of rice grain yields caused largely by the increasing effect of soil salinity. Rice is the second staple after maize in Tanzania, and also contributes to employment through various chains of its production and consumption. Updating the information on the challenge of salt-affected soils is expected to provide the appropriate management options, which will increase rice yield, farmer's income and food security. Therefore, this study was conducted to obtain the current situation of salt-affected soils from farmers' experiences and available options to cope with the challenge. This is the primary (key) information for the intervention of stakeholders, including researchers and policymakers, to find an appropriate management option and pay attention to the increasing level of food insecurity resulting from rice cultivated in salt-affected soils.

study showed that a majority (78%) of farmers attributed a decline in rice yield largely to salt-affected soils. The perception of farmers on the extent to which they experience salt-affected soils in their rice farms differed significantly ($\chi2 = 50.373$; $p = < 0.001$). In contrast, farmers' responses on salt-affected soils across the districts were not significantly ($\chi2 = 6.133$; $p = 0.408$) different, which is an interesting result indicating that salt constraints were equally important in rice producing irrigation schemes. Enhancing farmers' knowledge and providing effective and affordable management technologies can improve rice production in small land holdings affected by salts.

Subjects: Agriculture and Food; Soil Sciences; Land Reclamation Pedology

Keywords: improved livelihoods; irrigation schemes; soil health; salt stress; indigenous management practices

1. Introduction

Soil salinization is a global environmental threat altering land productivity and bringing impacts to agricultural production, environmental health, and economic welfare (Butcher et al., 2016; Cuevas et al., 2019). The effect of soil salinization has been reported globally in almost all countries with variations in their extent (Shahid et al., 2018). Approximately 1 billion ha of land is dominated by salt-affected soils (FAO & ITPS, 2015; Ivushkin et al., 2019). However, data on country-specific impacted soils is scarce, unavailable, outdated, or illusive (Omuto et al., 2020), but estimates indicate that 50% of all arable lands will become impacted by salinity by 2050 (Butcher et al., 2016). In Africa, more than 200 million ha of land contain salt-affected soils (FAO & ITPS, 2015) of which 19 million ha are found in Sub-Saharan Africa (Tully et al., 2015).

Tanzania is one of the countries in Sub-Saharan Africa with more than 2 million hectares of land with salt-affected soils (FAO, 2000). The extent of salt-affected soils has been identified as one of the factors reducing land productivity and farmer incomes, particularly in lowland areas (Kashenge-Killenga et al., 2013; Makoi & n.d.akidemi, 2007). In many rice (*Oryza sativa*) irrigation schemes, soil salinity is a major constraint for rice production and sustainability (Kashenge-Killenga et al., 2013; Makoi & n.d.akidemi, 2007; Meliyo et al., 2016). Available literature shows that 3.6 million ha of land had salt problems, with 83% saline and 16% sodic (Mnkeni, 1996). According to FAO (2000), soils in 1.7 million ha were saline, and 300,000 ha were sodic. Salt-affected soils are often found in alluvial plains and valleys influenced by the nature of the parent materials eroded by surface runoff or colluvial from highland areas (Mnkeni, 1996).

Rice is the second-largest produced and consumed cereal crop in Tanzania, with annual grain yields of about 3.3 million tons matching 1.7 million ha of the cultivated land area (NBS, 2021). More than 1.3 million households are engaged in rice production (NBS, 2021), of which productivity ranges from grain yields of 1.8 to 4.3 t ha^{-1} which is lower than the potential grain yield of more than 9 t ha^{-1} (Kwesiga et al., 2020). However, productivity varies based on the production ecosystem with higher production in rainfed lowland areas. The low grain yield is attributed, among other factors, to soil salinization (Kashenge-Killenga et al., 2013).

Salt stress affects crop productivity in various ways. Salinity impacts osmotic potential of soils (Minhas et al., 2020), physical and biochemical properties of the soil (Manuel et al., 2017), and it can cause nutrient imbalance and ion toxicity (Sarker & Oba, 2020) altering the physiological functions of the plant (Sarker & Oba, 2019). Osmotic stresses, for example, impair plants' ability to extract water from the soil resulting in signs of drought-stress even when sufficient water is available (Ferreira et al., 2019). The consequences of salts on plant and soil health have received much attention in many studies (Abu-Qaoud et al., 2021; Egamberdieva et al., 2019; Gupta et al., 2021; Kamran et al., 2020) due to its social economic impact on the community. The decline in agricultural harvest, low income, and change in livelihood preferences are among the social-economic impacts induced by salt-affected soils (Shahid et al., 2018). Strategies to cope with the problem of salts in soils could be a better understanding of spatial-temporal and long-term impacts on relevant and up-to-date information (Mukhopadhyay et al., 2021). However, the data available for many countries is illusive and the results reported are inconclusive (Omuto et al., 2020).

Tanzania, like other Sub-Saharan African countries, has inadequate information on salt-affected soils. The existing data on salt-affected is old and of a small scale, which may not be useful for project planning and decision making. Understanding the current situation of salt-affected soils from farmers' experiences and field investigations provides a roadmap for designing effective management techniques to overcome the problem. Farmers' perceptions of salt-affected soils have been used as the entry point for developing management strategies (Qureshi et al., 2019).

The Participatory Rural Appraisal (PRA) approach is useful for assessing farmers' perceptions of crop output limits induced by abiotic and biotic stresses (Mogga et al., 2019; Mrema et al., 2017; Srijna et al., 2020). The PRA method encourages the community to share opinions, ideas, and experiences about the local problems that often face the community (Abdullah et al., 2012; Campbell, 2001; Jha & Gupta, 2021). It is also regarded as a powerful tool to link different stakeholders including farmers and researchers (Abdullah et al., 2012); thus, interviews and group discussions among farmers generate useful information aiding the identification of research gaps. Therefore, this study aimed at exploring farmers' perceptions and knowledge of salt-affected soils, available management or coping techniques, and come up with appropriate management options for improved rice production. The information generated through this study is expected to help farmers, researchers, and policy-makers in planning and formulating appropriate policies and suggest suitable interventions for the adaptation and mitigation of the problem of salt-affected soils to improve food security and farmers' welfare and livelihood.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Mbarali and Iringa districts in the Southern Highlands in regions of Mbeya and Iringa respectively, and Same and Moshi districts in the Kilimanjaro region in Northern Highlands in Tanzania (Figure 1). The regions and selected districts were spatially distributed with high variability in physiographic features. Demographic characteristics of study districts are presented in Table 1.

2.2. Sampling design and procedures

This study used a purposive sampling protocol to identify districts, rice irrigation schemes, and farmers involved in the survey. In the first stage, four districts namely Iringa, Mbarali, Same, and Moshi were purposively selected and 12 irrigation schemes (i.e., 3 from each district) were identified and used for the study. The selection was based on the available information from previous studies, which indicated that the rice irrigation schemes in these districts have huge potential for increasing rice production but are constrained by salts (Kashenge-Killenga et al., 2016; Meliyo et al., 2016). Before starting this study, preliminary field observation survey was conducted in December 2020, where direct indicators, such as soil colour, salt deposition on the soil surface, and rice plants growing in patches were observed. Soil samples were collected randomly in some of the surveyed irrigation schemes for laboratory analysis. The selected irrigation schemes are indicated in Table 2.

A simple random sampling technique was deployed and 27 respondents representing rice growing farmers in each irrigation scheme were selected using the list of registered farmers from their associations except for one irrigation scheme where 26 farmers were included in the study. The

Figure 1. Map of Tanzania showing the location of the study districts.

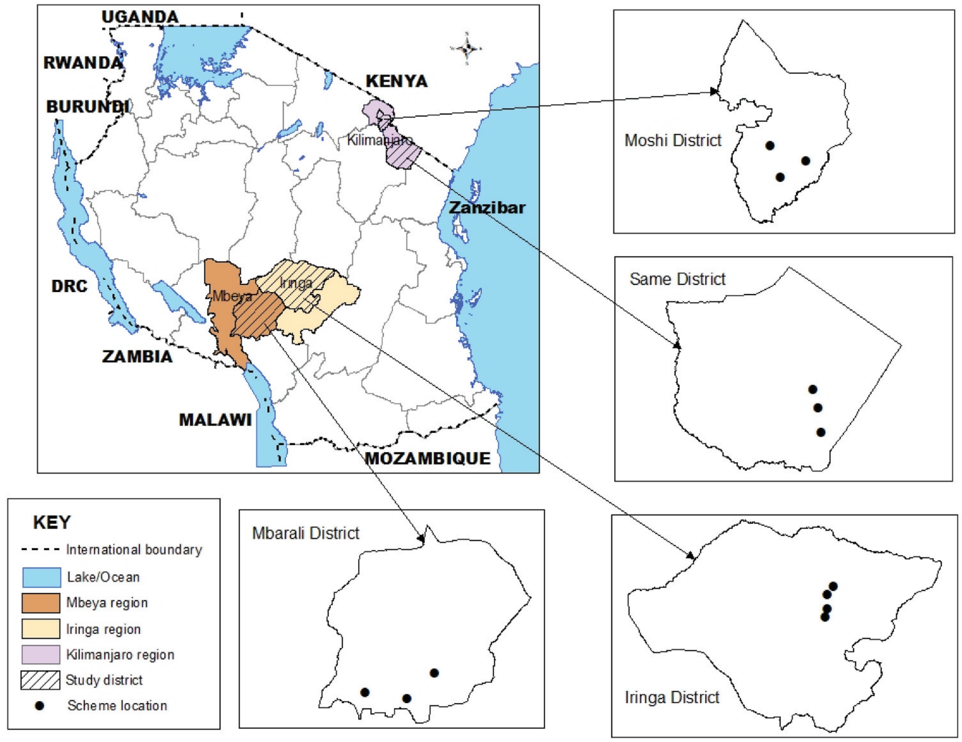


Table 1. Physiographic and climatic characteristics of the study districts

Items	Districts			
	Mbarali	**Iringa**	**Same**	**Moshi**
Location	Latitude 7°37’ to 8° 56’ S and longitude 33°33’ to 34°58’ E	Latitudes 6°53’ to 8°14’ S and longitude 34°11’ to 36°12’ E	Latitudes 3°47’ to 4°36’ and longitude 37°27’ to 38°24’ E	Latitude 3°5’ to 3° 39’ S and longitude 37°14’ to 37°36’ E
Altitude (m) above mean sea level (amsl)	1000–1800	800–1800	1100–2462 (Upland plateau), 900–1100 (Middle Plateau), and 500–900 (Lowlands)	750–1500
Mean annual rainfall (mm)	800 mm, from October to April or May, in a wet year and 450 mm in dry years. The dry spell starts from June to September	600–1000 from November to April	500–800 (March—June) long rainy season and from (November—December) short rainy season. The dry spells from July to October	1000–1500 (February—May) long rainy season and (November—December) short. The dry spell is from July to September
Temperature range	19 °C (June and July) to 32 °C (August to December)	Highest average temperature is 27 °C in October and the lowest average temperature of 11 °C in July	Maximum average temperature is 34 °C in October and the lowest average temperature of 24 °C	Highest average temperature is 30 °C in October and the lowest average temperature of 16 °C in July

Table 2. Location of irrigation schemes in the study districts

Region	District	Irrigation schemes	Location	
			Latitudes	Longitudes
Mbeya	Mbarali	Mwendomtitu	08°39’	34°20’
		Betania	08°44’	33°51’
		Uturo	08°47’	34°08’
Iringa	Iringa	Magozi	07°26’	35°28’
		Mlenge	07°21’	35°28’
		Mkombozi	07°18’	35°31’
Kilimanjaro	Same	Maya	04°17’	38°03’
		Kihurio	07°18’	35°31’
		Ndungu	04°22’	38°04’
	Moshi	Lower Moshi	03°24’	37°21’
		Mawala	03°31’	37°24’
		Soko	03°28’	37°29’

selection considered gender equity and rice farming experience (of not less than 5 years. Similarly, a total of 323 rice farmers (i.e., 81 from each district), except Same district (80 farmers) were randomly selected and interviewed using a semi-structured questionnaire. The total sample size of the respondents was obtained using the formula of Cochran (1977), as shown in Eq. 1.

$$n_0 = \frac{z^2 pq}{e^2} \quad (1)$$

Where n_o is the sample size, z is the selected critical value of the desired confidence level, p is the estimated proportion of an attribute that is present in the population, $q = 1–p$, and e is the desired level of precision. The assumption made was that 70% of the population of the selected villages engaged in rice farming. Therefore, the sample size (n = number of farmers interviewed) was determined using z = confidence level at 95% (standard value of 1.96), p = estimated proportion of an attribute (percentage of rice farmers in population), estimated at 70%, and e = desired level of precision at 5%.

$$P = \frac{z^2 pq}{e^2} = \frac{(1.96)^2(0.7)(1-0.7)}{(0.05)^2} = 322.69 \approx 323$$

Furthermore, 12 focus group discussions (FGDs, i.e., 1 from each irrigation scheme were formed for the purpose of acquiring relevant additional information for the study. The team composition was comprised of farmers, local leaders, village extension officers and key informants. Each focus group discussion consisted of 10 members, of which there were 8 representing farmers and 2 were irrigation schemes leaders.

A total of 120 farmers who participated in the survey were involved in the FGDs in the four selected districts. Apart from FGDs, the study also involved 24 key informants 2 from each irrigation scheme, (i.e., equal number of key informants for all irrigation schemes) purposively selected depending on their experience with rice production and familiarity with salt-affected soils environment of the study areas. Checklists were developed and used to guide FGDs of farmer groups and individual key informants. Field observations were part of validating some of the information and/or concerns raised during the interviews and group discussions.

2.3. Descriptive data collection

The study used primary and secondary sources to capture the necessary information from farmers and stakeholders. Group discussions, interviews with individual farmers and key informants, and field observations such as soil colour, salt deposition on the soil surface, and rice plants growing in patches were the key methods for the collection of primary data. Secondary data sources were district and village administrative officials and key informants at the district and village levels. Land characteristics in rice fields were observed during transect walks in the selected districts to provide complementary data. Semi-structured questionnaires containing open-ended and closed questions were administered to respondents in face-to-face interviews in January and February 2022. The questionnaires were designed to capture farmers' understanding and their knowledge on salt-affected soils, possible practices contributing to salt-affected soils, adaptation and management options as coping strategies. The data collected included farmers' demographics, rice production trends, farmers' land size, knowledge and perceptions of salinization problems, factors that influence soil salts occurrence, and management practices. Checklist questions were designed to capture all necessary information during group discussions. The farmers' responses on major constraints related to rice production were scored based on the severity of the problem (i.e., high, moderate, and low).

2.4. Triangulation of data

The follow-up discussion was made with lead farmers, key informants, and extension officers of the respective irrigation schemes to validate the information collected from the survey. The key questions used during the personal farmer's interview and FGDs were used to clarify the incomplete information. The use of the triangulation method increases the credibility and validity of research findings (Carter et al., 2014; Noble & Heale, 2019). Triangulation, by combining theories and observations in a research study, can help ensure that fundamental biases arising during data collection, both the qualitative and quantitative data, are overcome (Noble & Heale, 2019). This exercise was productive, helping to identify circumstances surrounding the key concept of salt-affected soils and omitting unacceptable information to improve the trustworthiness of results.

2.5. Descriptive data analysis

Data collected through interviews and group discussions were coded and analysed using the Statistical Package for Social Sciences software (SPSS) version 20. Descriptive statistics were computed using frequency means and percentages for various variables involved in the study. Cross-tabulation tables were constructed using chi-square tests at the probability p = 0.05 to analyse relationships between variables. The respondents' responses based on queries (yes/no type) were analysed through Cochran's Q test. Farmers coping mechanisms on salt-affected soils were prioritized through Kruskal Wallis H Test, with indigenous and scientific mechanisms compared separately.

2.6. Conceptual model

2.7. Soil sampling and laboratory analysis

Composite soil samples were collected randomly at depths of 0–30 cm from some of the surveyed irrigation schemes for laboratory analysis to examine the presence of salt in soils. The most important parameters determined were soil pH measured potentiometrically in water at a ratio of 1:2.5 soil: water ratio (Mclean, 1982), and electrical conductivity ($EC_{1:2.5}$) determined in 1:2.5 soil water suspension using an electrical conductivity meter as described by Thomas (1982). Exchangeable bases were determined by atomic absorption (Ca^{2+} and Mg^{2+}) and emission (Na^{+} and K^{+}) spectrophotometer (Moberg, 2000). Electrical conductivity measured at saturated paste extracts (ECe) is recommended as a standard method for assessment of the level of salinity hazard to plants (Richards, 1954), the method is tedious, time consuming, and requires skills and expertise to reach saturation point (Kargas et al., 2018). Therefore, the EC values obtained for different soils-to water ratio extracts are correlated to the ECe of soil saturation extract (Shahid, 2013). In this study, $EC_{1:2.5}$ was converted to (ECe) using linear regression (Eq. 2) developed by Isdory et al. (2021).

Table 3. General chemical properties of salt-affected soils			
Class	**Soil reaction (pH)**	**Electrical conductivity (EC) (dSm^{-1})**	**Exchangeable sodium percentage (ESP)**
Saline	< 8.5	> 4.0	< 15
Saline-sodic	> 8.5	> 4.0	> 15
Sodic	> 8.5	< 4.0	> 15

Source: Richards (1954). Diagnosis and Improvement of Saline and Alkaline Soils

$$ECe = 3.4954 \times EC_{1:2.5} \quad (2)$$

The exchangeable sodium percentage (ESP) was calculated in Eq. 3 (Chhabra, 2005; Qadir & Schubert, 2002; Richards, 1954).

$$ESP = \left(\frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \right) \times 100 \quad (3)$$

The classification of salt-affected soils was based on criteria derived by Richards (1954) as shown in Table 3.

3. Results

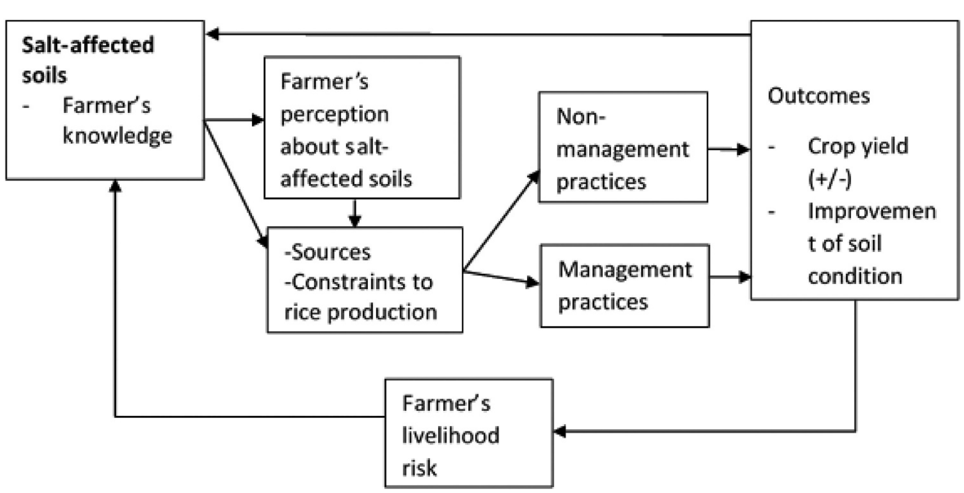
3.1. Demographic and socio-economic characteristics of farmers in the study irrigation scheme

The selected demographic attributes of the farmers in the study irrigation schemes are presented in Figures 3, 4 and 5. Results indicated that the majority of the respondents were male (63.2% of 323 respondents) higher than female (36.8%) though not statistically significant (χ^2 = 5.932; p = 0.115).

The proportion of males (63.2%) was greater than females (36.8%) across all the study irrigation schemes (Figure 2). Results indicated that neither males nor female proportion differed significantly (χ^2 = 5.884; *p* = 0.117) across the study irrigation schemes (Figure 3).

Majority of the respondents (84.5%) were aged between 25 and 60 years, while 11.8% were aged above 60 years and the rest (3.7%) were under 25 years (Figure 4). This indicated that all of

Figure 2. Conceptual model of salt-affected soils interaction with farmers' knowledge, management practices and risk to the livelihoods of farmers.



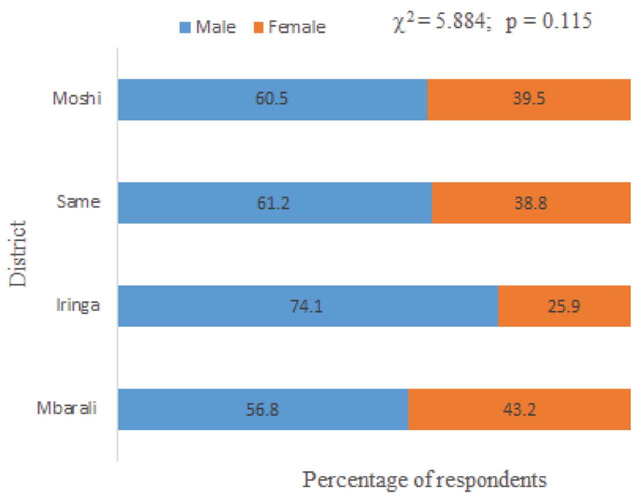


Figure 3. Gender distribution of the respondents.

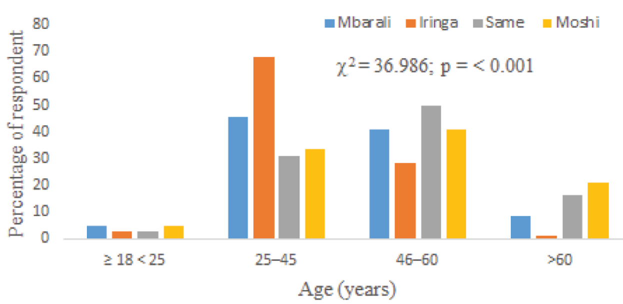


Figure 4. Age characteristics of the of the respondents.

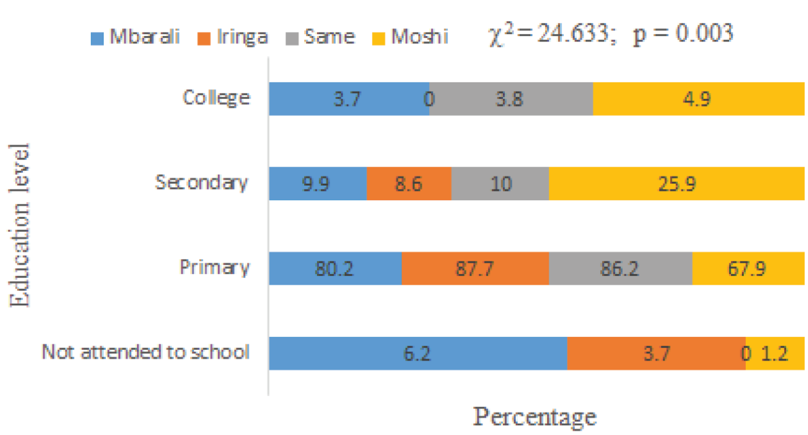


Figure 5. Education levels of the farmers in the studied irrigation schemes.

the respondents were adult (age > 18 years). Majority of the respondents (97.2%) at least attained primary education, and only a few (2.8%) did not undergo formal education (Figure 5).

Farmers in the studied irrigation schemes produce rice in a land area ranging from 0.4 to 12 ha (Table 4). A higher number of farmers (55.2 %) cultivate less than 1 hectare of rice. Very few respondents (3.7%) cultivate a large portion of land (> 4 ha). Results also indicated that 61.6% of the land is individually owned by farmers. The majority of the farmers (69.1%) cultivate improved rice cultivars, but mostly the cultivar SARO5 (TXD 306) in the studied irrigation schemes except for those in Iringa district, where local varieties are cultivated (Table 5). Many farmers (61.1%) experience a decreasing trend in rice yields with time, and based on their perception is attributed to several factors including the problem of salinization, shortage of irrigation water, poor soil fertility, and floods.

Table 4. Land size and land ownership in the surveyed irrigation schemes

		Percentage of respondents							
Characteristic	**Class**	**Mbarali (n = 81)**	**Iringa (n = 81)**	**Same (n = 80)**	**Moshi (n = 81)**	**Mean**	**χ^2**	**d. f.**	**p-value**
Land size (Hectare)	< 1	34.6	38.3	76.2	71.6	55.2	50.243	9	< 0.001
	1–2	46.9	48.1	22.5	19.8	34.3			
	2.1–4	11.1	8.6	1.2	6.2	6.8			
	> 4	7.4	4.9	0.0	2.5	3.7			
Land ownership	Own	61.7	65.4	65.0	54.3	61.6	18.049	9	0.035
	Family land	25.9	11.1	28.8	24.7	22.6			
	Borrow	0.0	1.2	0.0	1.2	0.6			
	Rent	12.4	22.3	6.2	19.8	15.2			

Note: χ^2 = Chi-square, d.f. = degrees of freedom, ($P < 0.05$) indicates that there is significant difference

The major rice production constraints in the study irrigation schemes in selected districts are summarized in Table 6. The identified constraints affecting rice production include salt-affected soils, high cost of fertilizers, poor irrigation infrastructure, poor soil fertility, disease, flood, pest, and poor quality seeds. Farmers' responses on salt-affected soils were not significantly ($\chi2 = 6.133$; $p = 0.408$) different across the districts, which are interesting results indicating that salt constraints are equally important in rice productizing irrigation schemes. Majority of the respondent (60.7%) reported the high cost of fertilizers as another important factor limiting rice production across all surveyed districts. Farmers also do not meet the required fertilizer application rates based on deficient soil nutrients, thus rendering in a reduction of rice yield. In addition, poor irrigation infrastructure scored third a high (35.3%) in constraints to rice production.

3.2. Awareness of farmers to salt-affected soils

Majority of the respondents (98.8%) were aware of salt-affected soils, and most of them (78.3%) had experienced the effect in their irrigated rice fields (Table 7). Results also indicated that the respondents' knowledge differed significantly ($X^2 = 401.485$; $p < 0.001$) about salt-affected soils and the experience they encountered (Table 7). However, the majority (80.8%) of the respondents were unable to differentiate between the types of salt-affected soils (i.e., saline, sodic, and saline-sodic). These are locally known by the farmers as "chumvi or magad" (i.e., saline or sodic respectively) based on the tongue testing. The main source of knowledge for the majority of the farmers (68.7%) on salt-affected soils was from their parents and/or other neighbouring farmers.

Table 5. Proportions of rice variety grown and production trends

		Percentage of respondents in irrigation schemes							
Variable	**Class**	**Mbarali (n = 81)**	**Iringa (n = 81)**	**Same (n = 80)**	**Moshi (n = 81)**	**Mean**	**χ^2**	**d. f.**	**p-value**
Variety grown	Local	1.2	61.7	2.5	1.2	16.7	21.514		< 0.001
	Improved	81.5	6.2	91.2	97.5	69.1			
	Both	17.3	32.1	6.3	1.3	14.2			
Rice production trend	Increase	34.6	17.3	16.2	34.6	25.7	16.61	6	0.011
	Decrease	54.3	75.3	68.8	58.0	64.1			
	Vary	11.1	7.4	15.0	7.4	10.2			

Note: χ^2 = Chi-square, d.f. = degrees of freedom, ($P < 0.05$) indicates that there is a significant difference

Table 6. Major constraints to rice production in surveyed irrigation schemes

Constraints	Severity	Percentage of respondents				Mean	χ^2	d.f	P-value
		Mbarali (n = 81)	Iringa (n = 81)	Same (n = 80)	Moshi (n = 81)				
Disease	H	0.0	0.0	12.5	8.6	5.3	47.826	6	< 0.001
	M	13.6	22.2	42.5	38.3	29.2			
	L	86.4	77.8	45.0	53.1	65.6			
Insect Pest	H	0.0	1.2	6.2	0.0	1.9	37.693	6	< 0.001
	M	14.8	13.6	35.0	7.4	17.7			
	L	85.2	85.2	58.8	92.6	80.5			
High cost of fertilizers	H	58.0	37.0	53.8	51.9	50.2	16.462	6	0.011
	M	17.3	8.7	11.2	12.3	10.3			
	L	24.7	54.3	35.0	35.8	39.5			
Poor quality seeds	H	0.0	0.0	0.0	0.0	0.0	11.370	3	0.01
	M	7.4	24.7	11.2	11.1	13.6			
	L	92.6	75.3	88.8	88.9	86.4			
Poor soil fertility	H	24.7	34.6	15.0	19.8	23.5	19.354	6	0.004
	M	19.7	25.9	12.5	17.2	18.8			
	L	55.6	39.5	72.5	63.0	57.7			
Salt-affected soils	H	71.6	75.3	51.2	48.2	61.6	24.479	6	< 0.001
	M	16.0	13.6	16.3	18.5	16.1			
	L	12.4	11.1	32.5	33.3	22.3			
Poor irrigation infrastructure	H	23.4	24.7	26.2	16.0	22.6	4.545	6	0.603
	M	13.6	14.8	12.5	9.8	12.7			

(Continued)

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Table 6. (*Continued*)

Constraints	Severity	Percentage of respondents				Mean	χ^2	d.f	P-value
		Mbarali (n = 81)	Iringa (n = 81)	Same (n = 80)	Moshi (n = 81)				
	L	63.0	60.5	61.3	74.2	64.8			
Drought	H	0.0	0.0	6.2	0.0	1.6	21.735	6	0.001
	M	12.3	8.6	11.3	2.5	8.7			
	L	87.7	91.4	82.5	97.5	89.8			
Flood	H	6.2	3.7	0.0	0.0	2.5	13.362	6	0.038
	M	22.2	19.8	27.5	14.8	21.1			
	L	71.6	76.5	72.5	85.2	76.5			

H, high severity; M, moderate severity; L, low severity; d.f, degrees of freedom.

Table 7. Farmers' awareness and knowledge of salt-affected soils			
Cochran's Q test			
Sample size	323	d.f.	2
Q	401.485	p-value	<0.001
Statistics:			
Variables	Sum	Proportional 1 (yes) %	Proportional 2 (no) %
Knowledge about salt-affected soil	323	98.8	1.2
Experience of salt-affected soil on their farms	323	78.3	21.7
Differentiate types of salt-affected soils	323	19.5	80.5

Results indicated that 78.0% of the farmers experienced the problem of salt-affected soils on their farms. This indicated that problems exist and are distributed to many arable lands.

The main source of knowledge for the majority of farmers (68.7%) on salt-affected soils was from their parents and/or other neighbouring farmers (Figure 6). Results indicated that 78.0% of farmers experienced the problem of salt-affected soils on their farms. This indicated that problems exist and are distributed to many arable lands.

3. 4. Sources of salt-affected soils

Across the studied districts, the majority of farmers (73.1%) perceived that parent materials were the major sources of soil salinization in rice farms (Figure 7). Poor irrigation infrastructure was the second source (37.6%), caused by the lack of outlet canals, which forces farmers to share irrigation water with the neighbouring farm. This situation is likely to transfer salts from the affected farm and induce them to another farm.

Based on district specific, flood was indicated as a major source of soil salinization in Iringa (31.5%) and Mbarali (25.3%) districts. Flooding occurs in many irrigation schemes during the rainy season, resulting in salt in fields if water is affected by salt.

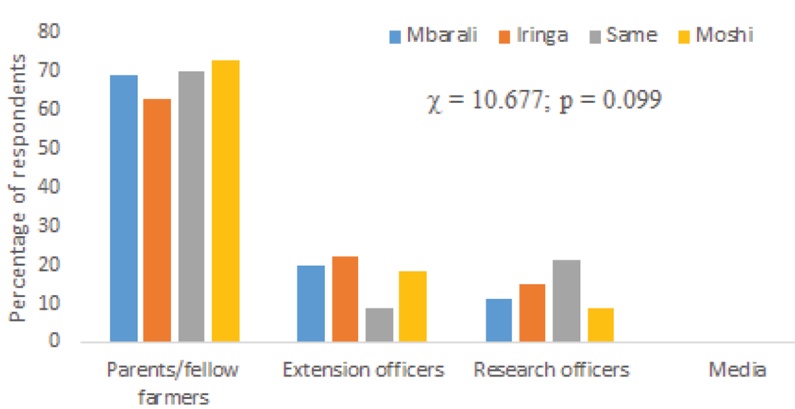
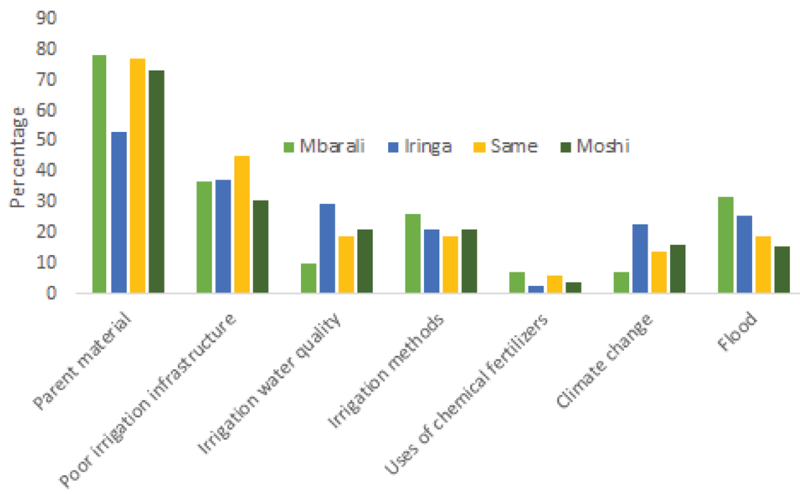


Figure 6. Farmers source of information of salt-affected soils.

Figure 7. Farmers' perception of the major sources of salt-affected soils in rice farms.



3.3. Farmers' knowledge of rice cultivars tolerant to salts

Farmers' knowledge of salt-tolerant rice cultivars was limited in the studied irrigation schemes. Results indicate that most of the respondents (81.7%) were not aware of rice cultivars tolerant to salt effects (Table 8). It was also realized that a few farmers (18.3%) had heard about rice cultivars tolerant to salts, although they were not used. The major reasons highlighted by farmers were the unavailability of seeds and the shortage of knowledge about these rice cultivars.

3.4. Farmers' perception of the extent of salt-affected soils in their rice farms

Farmers were aware of the increasing trend of soils affected by salts on their rice farms. The results from the respondents indicated that 72.4% of the farms were salt-affected by at least 25% of the entire farm (Figure 8). In addition, a few farms (4.0 %) suffered from salt-affected soils on the entire land.

3.5. Farmers' perception of coping mechanisms to salt effects on rice farms

Using excessive irrigation water (flushing) is a common method practiced by the majority of farmers in the surveyed irrigation schemes to minimize the negative impact of soil salinization, especially for saline soil. However, the practice is mainly dependent on water availability. Other indigenous methods reported were the use of farm yard manure (38.9%), burned rice straw (ashes) (13.0%), unburned rice husk (8.3%), and burned rice husk (6.7%). Other farmers also reported the use of gypsum (5.4%) and chemical fertilizers (7.4%) like ammonia sulphate ($(NH_4)_2SO_4$) (SA) as scientific methods that can be deployed to cope with the effect of salts on soils. However, more than 36% of farmers who experienced salt-affected soils on their farms did not use any other coping strategies except flushing. The lack of knowledge and the cost of implementation were the main reasons for not opting for other strategies except flushing. Details were described in Table 9.

3.6. Examined soil properties of studied irrigation schemes

The laboratory analysis results showed indication of salt-affected soils (Table 10). Soil characteristics were in line with farmers' perception of the existence of salt-affected soils in the surveyed irrigation schemes. Soil analysis in this study was meant to complement farmers' perceptions of the existence, distribution and extent of salts in the selected rice irrigation schemes.

4. Discussion

The extent of salt-affected soils and the decline in rice grain yield in rice-growing areas are considered to be increasing across the studied irrigation schemes, which are located in diverse physiographic agro-ecological zones. Salt-affected soils has been the major constraint to rice production resulting in low grain yields and/or total loss under extreme conditions. Under normal conditions (i.e., irrigation water availability; the tiny incidence of diseases and pests; and application of fertilizers) with

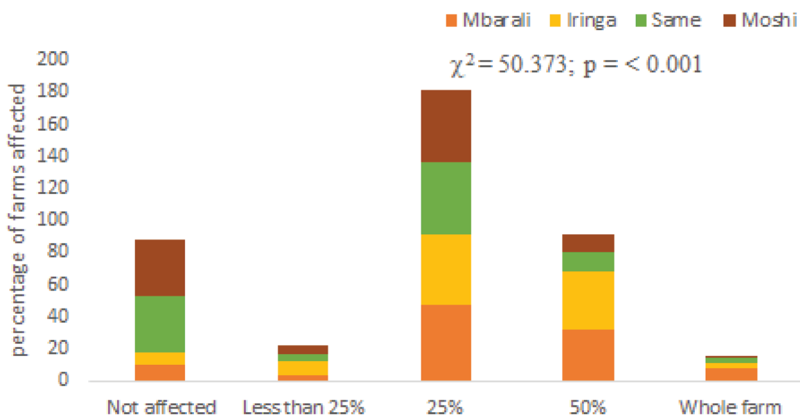


Figure 8. Perception of the extent of salt-affected from farmer's fields.

Table 8. Farmers' knowledge of rice cultivars tolerant to salts

Cochran's Q test			
Sample size	323	d.f.	1
Q	50.0	p-value	<0.001
Statistics:			
Variables	Sum	Proportional 1 (yes) %	Proportional 2 (no) %
Knowledge about salt-tolerant cultivars	323	18.3	81.7
Use of salt-tolerant cultivars	323	0.0	100.0

unnoticeable levels of salinity or sodicity farmers' reported harvest ranges from 3.2 t/ha to 3.8 t/ha. Whereas, under the effect of salt-affected soils, farmers' harvest ranges from 0.4 t/ha—0.95 depending on the levels of salinity of sodicity. Kashenge-Killenga et al. (2016), reported rice grain yield losses in irrigation schemes ranges from 5 to 100 %. Depending on the severity of salinity/sodicity.

According to farmers' views, the nature of the underlying parent materials and the induction of salty water during the rainy seasons through floods were the main causes of salts occurrence on the farms. The influence of salt-affected soil causes yield losses in rice irrigation schemes that ranges from 5 to 100% (Kashenge-Killenga et al., 2016).

The present study found that some fields have been abandoned and farmers are progressively shifting to cultivating other crops in upland areas. These findings corroborate with a study by Kashenge-Killenga et al. (2014) that there is a decrease in rice grain yield in irrigation schemes of Tanzania is attributed to high levels of salinity and sodicity (i.e., ECe ranged from 4–15 dSm^{-1} for saline soil and Sodium adsorption ratio (SAR) of 10–34 for sodic soil). Other constraints to rice production apart from salt-affected soils include cost of fertilizers; poor irrigation infrastructure such as inadequate outlet canals; outbreaks of diseases; poor soil fertility; harsh weather conditions (floods; drought); invasions from insect pests and poor-quality seeds. These constraints were also reported in previous studies conducted in Tanzania (Hashim et al., 2018; January et al., 2018; Suvi et al., 2020) and other parts of Sub-Saharan Africa (Bjornlund et al., 2020; Tsujimoto et al., 2019).

The inherent characteristics of the in situ salt formation in soils are perceived by the majority of farmers to be the main sources of salt-affected soils. Furthermore, poor irrigation infrastructures were also identified as the sources of salt-affected soils and can accelerate the problem due to limited outlet canals that force farmers to share the already used irrigation water with nearby

Table 9. Farmers' perception on coping mechanisms for salt-affected soils

Practices Methods	Type of practices Application of:	N	Mean of Ranking	Chi-Square	[a]d.f.	p-value
Indigenous	manure	95	134.54	19.836	4	0.001
	Unburned rice husk	22	143.57			
	Burned rice husk	16	130.44			
	Burned rice straw	30	161.30			
	Not using	90	102.94			
Conventional						
	gypsum	12	190.58	23.941	2	< 0.001
	chemical fertilizers	21	69.24			
	Not applicable	220	129.05			

[a]d.f. = degrees of freedom

farms. The findings of the present study show that the majority of the respondents were knowledgeable about salt-affected soils conforming with the findings reported by Kashenge-Killenga et al. (2014). Most of the farmers grouped all types of salt-affected soils into one category, "*Magadi*", as they failed to differentiate the commonly known classes depending on the salt levels. In this study, it was found that the majority of farmers were able to recognize indicators of salt-affected soils by using soil colour, fragmented growth of rice, and salts deposited on the soil surface. The main source of knowledge was experience gained from parents and/or fellow farmers. Formal knowledge from the experts was limited among the farmers in all surveyed irrigation schemes.

Farm size is a key factor determining food self-sufficiency and a household's ability to grow above the poverty margin (Giller et al., 2021). It is among the factors that influence farmers' revenue from farm output of cultivated land the most (Noack & Larsen, 2019).

A previous study conducted in four countries (Ethiopia, Tanzania, Ghana and Malawi), revealed that only a small proportion of farming households can achieve a living income due to land constraints (Giller et al., 2021). The present study found that the majority of farmers grow rice on a farm size of less than 1 ha. This is an indication of insufficiency rice production in many households, and therefore they only seek to meet the demand for food for family consumption. Furthermore, farmers have indicated that salt-affected soils cause significant yield losses in their farms. Qadir et al. (2014) estimated the global annual income losses of crops from salt-affected soils in irrigated areas to be about US$27.3 billion which a very significant loss incurred by farmers all over the world, underscoring that this is a problem worth working out best bet technologies for its management.

The present study revealed that the majority of the farmers in the studied districts have shifted from using local to improved rice cultivars. Rice variety SARO5 (TXD 306) although is a very old (>15 years) variety but it is widely cultivated due to its high-yielding and is relatively tolerant to salinity stress compared with landraces (Kashenge-Killenga et al., 2016). These findings contrasted with other studies that showed low adoption of improved cultivars due to poor farmers' preferences for grain traits such as aroma (Kangile et al., 2018; Suvi et al., 2020). Only in the irrigation

Table 10. Soil analytical results for some of surveyed irrigation schemes

Irrigation Scheme	pH	EC	ECe	ESP	Salt classes
	H_2O	1:2.5			
Ndungu (N = 12)	7.74	2.96	10.35	3.52	Saline
	8	0.48	1.67	1.48	Salt free
	7.7	2.96	10.35	3.52	Saline
	7.9	3.51	12.27	4.54	Saline
	8.21	0.33	1.16	1.33	Salt free
	8.06	0.48	1.68	1.67	Salt free
	7.93	3.51	12.27	4.53	Saline
	7.89	4.73	16.53	5.22	Saline
	7.72	4.56	15.94	4.17	Saline
	7.46	5.89	20.59	3.51	Saline
	7.51	4.62	16.15	3.03	Saline
	7.63	5.51	19.26	3.44	Saline
Magozi (n = 10)	8.52	0.1764	0.62	13.82	Salt free
	6.76	0.613	2.14	12.66	Salt free
	6.49	0.486	1.70	15.10	Salt free
	5.76	0.297	1.04	10.38	Salt free
	7.85	0.333	1.16	9.36	Salt free
	8.21	1.535	5.37	49.99	Saline sodic
	6.72	0.451	1.58	12.65	Salt free
	7.48	4.38	15.31	50.69	Saline sodic
	8.14	2.2	7.69	44.40	Saline sodic
	7.4	0.994	3.47	12.36	Salt free
Lower Moshi (n = 6)	9.42	1.243	4.34	13.61	Salt free
	9.06	0.984	3.44	18.35	Sodic
	9.2	1.121	3.92	15.95	Sodic
	9.4	4.24	14.82	21.00	Salt free
	8.39	1.256	4.39	8.31	Saline
	8.7	0.991	3.46	17.88	Sodic

schemes in Iringa district, where the majority of farmers had continued to grow the local cultivars of rice because of their preferences in the local market.

Farmers have adopted indigenous methods such as the use of farm yard manure (FYM), unburnt rice husk, burned rice husk, burned rice straw, and flushing as coping mechanisms for the emerging challenges of salt-affected soils. Flushing is a common and well-known practice, but the major challenge is inadequate outlet canals, poor drainage and associated salinization represent severe threats to the long-term sustainability of irrigated agriculture in many irrigation schemes (Mohanavelu & Naganna, 2021; Singh, 2019; Tomaz et al., 2020). The application of manure is the most widely reported indigenous method depending on its availability in some of the areas of studied irrigation schemes and awareness among farmers due to its importance to soil improvement. However, the method has been reported to be ineffective in reducing the impact of salts in soils due to inadequate drainage structures. Existing studies (Hashim et al., 2018; Kashenge-Killenga et al., 2014; Suvi et al., 2020) show that training regarding rice production constraints is likely to influence farmers' engagement in management practices based on available management options.

Gypsum as reported by Ahmed et al. (2017), Bello et al. (2021), and Lastiri-Hernández et al. (2019) is the most important and effective soil amendment among the widely known and used materials for reclaiming salt-affected soils as it can remove excess sodium in exchange sites and increase the availability of several nutrients, including phosphorus (P). The findings of the present study revealed that a few farmers used gypsum in lower quantities than the recommended rate due to the costs of transportation.

5. Conclusion and recommendations

The present study explored the farmers' perceptions and awareness of salt-affected soils and assess the coping mechanisms in rice irrigation schemes in the selected irrigation schemes of Tanzania. It is concluded that salt-affected soils are the major constraints limiting rice production in the studied irrigation schemes. Farmers coping mechanisms for salt-affected soils were based on materials that are locally available and affordable, such as burned rice husk/straw and farm yard manure. Farmers are facing a knowledge gap on modernized options for tackling the effect of salts on rice production, such as the use of gypsum and salt-tolerant cultivars. Therefore, this study recommends: 1) systematic breeding of salt-tolerant rice cultivars; 2) critical soil characterization to identify the types of salt-affected soils and their extent; 3) develop effective and affordable soil management options; 4) strengthening farmers' management options to enhance rice production.

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