SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

A Cross-Sectional Study on the Effect of Saltwater Intrusion on Saro Rice Farming in Tovuni Kiungoni, Zanzibar, Tanzania.

Abdi Mzee Kitwana, Henry Stanley Mbowa, Eric Niringiyimana*
Graduate School and Research, Kampala University.

Abstract.

Background.
Saltwater intrusion poses a significant threat to agricultural productivity in coastal regions, particularly in Tovuni Kiungoni, Zanzibar, where Saro Rice Farming is a vital economic activity. This study investigated the effects of increasing salinity on rice cultivation, focusing on changes in soil salinity, crop yield, and farmer adaptations.

Methodology.
Through field surveys, soil sampling, and interviews with local farmers, the research identifies key contributors to escalating salinity in irrigation water, including rising sea levels and unsustainable water management practices.

Results
34% of the respondents were aged 60 years and above, and Females dominated the study at 62%. The findings reveal that elevated levels of sodium (Na^+) and chloride (Cl^-) ions exceed thresholds for optimal rice production, causing osmotic stress, reduced germination, stunted plant growth, and lower yields. Additionally, soil sodicity degrades soil structure, reduces infiltration, and exacerbates these challenges. Farmers have adopted strategies such as salt-tolerant rice varieties, improved irrigation techniques, and leaching practices, but their effectiveness is hindered by limited resources and knowledge.

Conclusion.
Elevated levels of sodium and chloride in irrigation water not only reduce the osmotic potential, making it difficult for crops to absorb water but also lead to soil degradation through sodicity. These effects ultimately compromise crop yields and agricultural sustainability in the region.

Recommendation.
There is an urgent need for integrated water resource management, sustainable agricultural practices, research on resilient crop varieties, and enhanced support systems to bolster farmer resilience. Collaborative efforts among stakeholders are essential to safeguard Saro Rice Farming, ensure food security, and address the growing impacts of climate change and environmental degradation in the region.

Keywords: *Saltwater intrusion, Saro rice farming, Soil salinity, Tovuni Kiungoni, Zanzibar agriculture.*
Submitted: *2025-03-11* ***Accepted:*** *2025-07-20* ***Published:*** *2025-10-01*

Corresponding Author: Eric Niringiyimana*
Email: *ericniringiye13@gmail.com*
Graduate School and Research, Kampala University.

Background.

Saltwater intrusion is projected to impact 380 million hectares, which is roughly one-third of the world's rice land. Complex saline intrusion is currently affecting many coastal regions, including Bangladesh, Orissa, Vietnam, and the Philippines (Su et al., 2025). In the dry season along peninsular Thailand, the rice sector faces challenges due to insufficient water supply from surface runoff. Recent influences from subsurface flow, tidal effects, and the shallow nature of natural water resources have rendered the water quality unsuitable for agriculture (Boonwichai et al., 2021). Farmers must adapt their practices to address these issues, and developing the ability to cope is crucial for managing recurring dangerous situations (IPCC, 2011; IPCC, 2017). Preparations may include training for responses to disturbances and mitigation efforts after such events.

The use of poor-quality water in agriculture leads to the degradation of soil physical properties and reduces crop production (Ingrao et al., 2023). Historically, irrigation agriculture has played a crucial role in ensuring rice security for billions; however, current prospects are concerning due to low crop yields and land degradation (Liu et al., 2024). Salinization is identified as a significant cause of land degradation and declining productivity in many irrigated areas.

Guimond (2021) notes that rice is increasingly becoming a commercial crop in Tanzania, providing food, employment, and income for both rural and urban populations. It is the second most important food crop after maize, with significant cultivation among rural households. The rice industry supports the livelihoods of approximately 2.2 million people (URT 2019, URT 2009). With the growing demand for rice due to population increases, the rice value chain has gained political significance in Tanzania.

Saro rice farming in TovuniKiungoni, Zanzibar, is a critical agricultural practice that contributes significantly to the local economy and food security of the region. Zanzibar, an archipelago off the coast of Tanzania, relies heavily on agriculture, with rice being one of the staple crops consumed by its population. In areas like TovuniKiungoni, rice farming is predominantly carried out by smallholder farmers who depend on it for both subsistence and income generation.

The introduction of Saro rice, a high-yield and disease-resistant variety, has revolutionized rice farming in the region. Saro rice is specifically bred to thrive in tropical climates, making it ideal for Zanzibar's conditions, where high humidity and intermittent rainfall can pose challenges for traditional rice varieties. The variety has been pivotal in increasing productivity per hectare, reducing the gap between local production and the high demand for rice (Moshi et al., 2021). Irrigation systems are central to the success of Saro rice farming in TovuniKiungoni. Unlike rain-fed agriculture, which is susceptible to climatic variability, irrigation schemes provide a reliable water supply, ensuring consistent crop growth throughout the year. Many farmers in the area have adopted water management practices supported by government programs and non-governmental organizations, aiming to improve food security and reduce rural poverty (Yadav et al., 2024).

In addition to government support, international agricultural initiatives have played a role in promoting modern farming techniques, such as the use of fertilizers, pest control methods, and mechanization. These efforts aim to transition Zanzibar's agriculture from traditional, low-input methods to more sustainable and productive practices. Farmers have also benefited from cooperative structures, which facilitate access to markets and credit facilities (FAO, 2020).

Despite these advancements, challenges remain. Limited access to inputs, such as certified seeds and fertilizers, and the lack of advanced farming equipment hinder some farmers from fully realizing the potential of Saro rice. Moreover, climate change poses risks, with rising sea levels and salinization of water sources threatening the viability of rice farming in low-lying coastal areas like Zanzibar (IPCC, 2022). Addressing these issues requires continued investment in infrastructure, farmer training, and sustainable practices. Saro rice farming in TovuniKiungoni represents a significant advancement in Zanzibar's agricultural sector. It offers a promising solution to food security challenges, provided that farmers continue to receive adequate support to overcome barriers to production.

Agriculture in Zanzibar contributes 55% of the GDP, provides 80% of employment, accounts for 60% of exports, and generates about 40% of government revenue (Modi, 2019). Irrigation alone contributes 3% to the total GDP and provides 18% of the value of all rice produced. However, the main constraints to rice production in Zanzibar include saltwater intrusion, sodicity, drainage issues, effective rooting depth, oxygen availability for root growth, soil workability, water retention capacity, moisture availability, soil fertility, germination conditions, ease of land clearing, and flexibility in field layout.

The increased and frequent use of irrigation in fragile regions to supplement rice production exacerbates naturally occurring saline soils. About 16,000 hectares of irrigated soils in Zanzibar are considered salt-affected due to poor-quality water, inadequate drainage, and ineffective irrigation management, especially in areas with rising groundwater tables (Omar et al., 2023). Many irrigation schemes in the country have been abandoned within 20 years of operation due to salinization, and without preventive and mitigation measures, many more are likely to follow. Saline soil is predominantly naturally formed and develops slowly through pedogenic processes. This study investigated the effects of increasing salinity on rice cultivation, focusing on changes in soil salinity, crop yield, and farmer adaptations.

Methodology.

Research design.

The study employed an experimental research design to investigate the interaction between independent and dependent variables, aiming to establish cause-and-effect relationships.

A total of 50 ml of each water sample was measured into 100 ml beakers, to which 5 ml of concentrated nitric acid was added. Following this, 5 ml of distilled 1:1 hydrochloric acid (HCl) was introduced. The mixtures were then heated on a hot plate (without boiling) until the volume was reduced to approximately 15–20 ml. An additional 5 ml of concentrated nitric acid was added, and the heating continued for another 5 to 10 minutes before allowing the mixtures to cool. Subsequently, the pH of the digested samples was adjusted to 4 by incrementally adding 5.0M Sodium Hydroxide Standard Solution. Finally, the solutions were transferred into 100 ml digestion bottles and topped up to the brim with distilled water, ensuring proper preparation for further analysis.

Sampling procedure

Water samples were collected from various sites whose GPS locations were noted in June 2024. Water samples were collected in June because rainfall was minimal (a mean of 52.3 mm), evaporation was high (a mean of 159.1 mm), and temperatures sometimes reached a maximum of 29.2°C. It was the year when the concentrations of most parameters were high or increased. Additionally, it was the time when most farmers irrigated. Samples were collected from 4 rivers, 9 streams, 2 dams, 2 ponds, 2 water pans, 5 shallow wells, and 2 boreholes into 500 ml plastic bottles (Plate 3.5). In total, fifty-two (52) samples were collected from twenty-six (26) sources, with two (2) samples taken per source. The bottles were cleaned before use in the field by washing with detergent and tap water, followed by sequential rinses with tap water, soaking in 10% nitric acid, and finally rinsing with deionized water and drying. At the sampling points, bottles were rinsed thrice with the water being sampled before samples were collected. Samples from rivers and streams were collected from well-mixed sections 20 to 30 cm below the surface. Although the same depth was applied for the dams, ponds, and water pans, samples were taken at the edges or banks due to a lack of access to the midpoints. Groundwater samples were collected after running taps (purged) for five to ten minutes. Samples were filtered in the field using a Sartorius polycarbonate filtering apparatus and 0.45 µm cellulose acetate filter membranes. Non-talc nitrile gloves were worn during the filtering of the samples. Each bottle was filled to the brim with the sample water and tightly sealed as quickly as possible to avoid exposure to air. They were then taped shut to prevent leakages. The bottles were wiped dry and clearly labeled using permanent ink and high-quality labels. Each labeled sample was recorded in a field book with a unique number and exact sampling location. The samples were kept in an icebox and transported to the Kampala University laboratory, where they were stored in the refrigerator at 4°C before analysis. All samples were analyzed within 24 hours. There were no contaminations from rain since no samples were taken in the rain. The bulb end of the temperature electrode was carefully placed into the beaker of water, and the temperature was determined after 2 minutes of waiting for the reading to stabilize. The pH electrode was immersed in the sample and stirred gently, then allowed to stabilize for 1-2 minutes before recording. Water EC was measured using the EC electrode of the multi-electrode water testing kit (portable OakTon 510 series). The conductivity cells and beaker were rinsed with a portion of the sample. The beaker was filled, and the cell was inserted into the beaker. The temperature control was adjusted to that of the sample, and the probe was inserted into the vessel, with the conductance read. The conductance was equilibrated to 25°C before readings were taken.

Laboratory analysis

Chemicals and reagents preparation.

Ultra-pure water was used throughout the study. The chemicals and reagents used were tabulated and prepared as follows:

Standard Calcium stock solution (1000 mg/L) was prepared by dissolving 5.00 g of $CaCO_3$ (Fluka, 99%) in double-distilled water and diluting to 1000 mL.

Standard sodium stock solution (1000 mg/L) was prepared by dissolving 2.54 g of NaCl (Sigma, 99%) in double-distilled water and diluting it to 1000 mL.

Standard Magnesium stock solution (1000 mg/L) was prepared by dissolving 6.1 g of $Mg(NO_3)_2$ (Fluka, 99%) in double-distilled water and diluting to 1000 mL.

Standard potassium stock solution (1000 mg/L) was prepared by dissolving 1.90 g of KCl (Fluka, 99%) in double-distilled water and diluting it to 1000 mL.

A standard silver nitrate stock solution (0.0282 M) was prepared by dissolving 4.791 g of $AgNO_3$ (Fluka, 99%) in double-distilled water.

Phenolphthalein indicator was prepared by dissolving 1 g of phenolphthalein (Merck, 99%) in 100 mL of methanol.

Methyl orange indicator was prepared by dissolving 1 g of methyl orange (Merck, 99%) in 100 mL of methanol.

H_2SO_4 solution (0.02 M) was prepared by diluting 0.55 ml of concentrated H_2SO_4 (Merck, 96% sp gr 1.84) to 1000 ml with distilled water.

M EDTA was made by dissolving 3.723 g of EDTA sodium salt (Sigma-Aldrich) and diluting it to 1000 mL with distilled water.

200.0 g of NaOH was dissolved in 500 mL of deionized water, cooled, and diluted to 1.00 L with deionized water.

10 ml of concentrated HCl was mixed with 500 ml of deionized water.

10 ml of concentrated HNO_3 was dissolved in 200 ml of deionized water.

5.0 g of K_2CrO_4 was dissolved in 100 ml of deionized water.

Table 1: The properties of chemicals and reagents

Item No.	Reagent	Concentration	Company	Purpose
1	Ca (CO_3)	1000mg/L	Fluka	Stock solution
2	NaCl	1000mg/L	Sigma-Aldrich	Stock solution
3	$AgNO_3$	(0.0282M	Fluka	Stock solution
4	Phenolphthalein indicator	1g/100Ml	Merck	Reagent
5	Methyl orange indicator	1g/100Ml	Merck	Reagent
6	EDTA	0.01M	Sigma-Aldrich	Reagent
7	KCl	1000mg/L	Fluka	Stock solution
8	$Mg(NO)_3$	1000mg/L	Fluka	Stock solution
9	H_2SO_4	0.02M	Merck	Reagent
10	HCl	Conc	Sigma-Aldrich	Reagent
11	NaOH	5.0M	Fluka	Reagent
12	HNO_3	Conc	Sigma-Aldrich	Reagent
13	K_2CrO_4	5%	Merck	Reagent

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Determination of ions in water samples.

A complete irrigation water quality (Saltwater intrusion and sodicity) analysis is taken to determine the following, as stated by Shahinasi and Kashuta (2018) and Fipps (2014);

The relative proportion of all cations (Na+, Ca2+, Mg2+, K+)

$$Calcium = \frac{M \times V \times 1000}{Vsample} \times 40 \ldots\ldots 3.4$$

The relative proportion of all anions (Cl-, SO42-, HCO3-, CO32- , NO3-)

Alkalinity (Bicarbonate and carbonate)

Fifty milliliters of the samples were measured into conical flasks, and 3 drops of phenolphthalein indicator were added to each. These were titrated with 0.02 M H_2SO_4 solution until the pink color disappeared. The volumes of the added H_2SO_4 were noted. Two drops of methyl orange indicator were then added to the same mixtures, and titration continued until the yellow color changed to orange.

The volumes of the added H_2SO_4 were also noted. These endpoints were the selected equivalence points for the determination of carbonate and bicarbonate ions.

The pH 8.2 phenolphthalein endpoint approximated the equivalent concentrations of carbonate, and the pH 4.4 methyl orange endpoint approximated the equivalence point for bicarbonate ions and allowed for the determination of the total alkalinity of the water.

$$Bicarbonate\left(\frac{mg}{L}\right) = \frac{2M \times (Vmoep - Vpep) \times 1000}{Vsample} \times 61 \ldots\ldots 3.1$$

The concentration of HCO_3^- and total alkalinity were

$$Alkalinity\ as\ CaCO_3\left(\frac{mg}{L}\right) = \frac{Vmoep \times M \times 50000}{Vsample} \ldots\ldots 3.2$$

calculated with equations 3.1 and 3.2, respectively, using an Excel spreadsheet. However, the concentrations of CO_3^{2-} were so insignificant that therefore were calculated from pH and alkalinity.

Where:

$$Magnesium = \frac{M \times (V2 - V) \times 1000}{Vsample} \times 24 \ldots\ldots 3.6$$

M = moles or concentrations of H_2SO_4

V*pep* = Volume of H_2SO_4 to reach phenolphthalein endpoint

V*moep* = Volume of H_2SO_4 to reach the me

M = Molarity of H_2SO_4

Hardness (magnesium and calcium)

Fifty ml of the sample was pipetted into a conical flask, and 1 ml of a buffer solution was added to produce a pH of 10. One gram of Eriochrome Black T indicator was also added. It was then mixed constantly and titrated with a standard 0.01 M EDTA until the last trace of purple disappeared and the color turned bright blue. Total hardness was then calculated using equation 3.3.

Where:

M = concentration of EDTA, V =volume of EDTA

Chloride.

50 ml of sample was taken, and 1 ml of K_2CrO_4 indicator solution was added, and then titrated with standard $AgNO_3$ titrant to a pinkish yellow endpoint. The reagent blank value was established by titrating 50 ml of distilled water with 1 ml of K_2CrO_4 dropped into it against standard $AgNO_3$. The value was calculated using equation 3.5. The experiment was repeated for all the samples.

Where:

V*sample* = Volume of sample

V*blank* = Volume of blank reagent

M = Molarity of $AgNO_3$

$$Chlorine = \frac{(Vsample - Vblank) \times M \times 35.450}{Vsample} \ldots\ldots 3.5$$

Magnesium.

Magnesium present in the samples was calculated by subtracting the volume of EDTA solution required for the calcium determination from the volume required for the total hardness determination (equation 3.6) for equal volumes of the sample. Then, 1 ml of 0.01M EDTA was equated to 0.2432 mg of magnesium.

Where:

M = concentration of EDTA

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

V2 = volume of EDTA for the determination of hardness
V = volume of EDTA for the determination of calcium

Nitrate

The determination of nitrate (NO_3^-) concentration was done using the Hydrazine Reduction Method. A 10.0 ml sample was pipetted into a test tube. One mL of 1.3 M NaOH (aq) was added and mixed gently. Nitrate was reduced to nitrite by heating (37°C) an aliquot of the sample with 1.0 ml of hydrazine sulfate in alkaline media and mixed gently; this reaction was catalyzed by the addition of cupric ion. The resulting nitrite, together with the original nitrites, reacted with sulphanilamide to form a diazo compound. This compound was then reacted with N-(1-naphthyl) Ethylene diamine dihydrochloride to form an azo dye in acid media. The absorbance of the light red azo dye was measured at 520 nm, and the concentration of nitrate nitrogen plus nitrite nitrogen was determined by comparison with a similarly treated series of mixed standards. Nitrate was calculated by subtracting the nitrite result from the nitrite plus nitrate result.

Potassium

This was done at an emission intensity of wavelength 766.5 nm on the Sherwood Flame Photometer Model 410. Blank and potassium calibration standards were prepared in ranges of 0 to 10 mg/L. A calibration curve from the potassium standards was then plotted. Distilled water was aspirated to adjust the scale reading to a zero deflection (0%) reading. The 1.0 meq/L standard solution was aspirated, adjusting the scale reading to full deflection (100%). Then the water samples were aspirated using a flame photometer to record the emission values. The concentrations of potassium in water samples were determined from the calibration graph. After every ten sample readings, the machine was recalibrated to ensure readings were within the 1.0 meq/L range.

Sodium.

This was done at an emission intensity of wavelength 589.0 nm on the Sherwood Flame Photometer Model 410. Blank and sodium calibration standards were prepared in ranges of 0 to 10 mg/L. A calibration curve from the sodium standards was then plotted. Distilled water was aspirated to adjust the scale reading to a zero deflection (0%) reading. The 1.0 meq/L standard solution was aspirated, adjusting the scale reading to full deflection (100%). Then the water samples were aspirated using a flame photometer to record the emission values. The concentrations of sodium in water samples were then determined from the calibration graph. After every ten sample readings, the machine was recalibrated to ensure readings were within the 1.0 meq/L range.

Sulphate.

Sulfate ion was precipitated in an acidic medium with barium chloride to form a barium sulfate crystal. The absorbance of the $BaSO_4$ suspension was measured by a

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \text{ .... Equation 3.10}$$

photometer at 420 nm, and the sulfate concentration was determined by comparison of the reading with a standard curve. A 50 ml sample was measured and diluted to 100 ml in a 250 ml Erlenmeyer flask. Five ml of conditioning reagent was added and mixed by stirring. A spoonful of barium chloride crystals was added while still stirring and timed for a minute at a constant speed. After stirring, the absorbance was measured at 420 nm on the spectrophotometer-Ultraspec model II, within plus or minus 0.5 of 5 minutes. The result was read directly from the calibration curve and expressed in mg/L.

Data processing and analysis

The data collected was first pre-processed. This was basically done through cross-checking to ensure that data

$$RSC = \{[HCO_3^-] + [CO_3^{2-}]\} - \{[Ca^{2+}] + [Mg^{2+}]\} \text{ .... Equation 3.11}$$

$$\frac{cation}{anion} balance = \frac{\sum cation\left(\frac{meq}{L}\right) - \sum anion\left(\frac{meq}{L}\right)}{\sum cation\left(\frac{meq}{L}\right) + \sum anions\left(\frac{meq}{L}\right)} \text{ .... 3.7}$$

from the laboratory was accurate, meaning that the sum of all cations was equal to or approximately the sum of all anions in milli equivalents per liter (meq/L). The accuracy of laboratory results was estimated using the balance error equation expressed in percentages.

A balance error was considered acceptable when it was less than 5% (Deutsch, 1997). All the water samples were within the acceptable error level. This was done to ensure the precision, reliability, and relevance of the data to the study. The data was then entered into Microsoft Excel version 2010, coded, and transported to SPSS 17.0 for statistical analyses. Summary statistics, such as mean and standard deviation for all independent variables concerning sample identities, were generated. Descriptive statistics, such as bar graphs and tables, were used to display results and explain objectives. Objective one was achieved by comparing the major salt ions data from the laboratory to accepted standards. Traditionally, salinity in water was commonly reported in units of Total Dissolved Salts or Solids (TDS) using the gravimetric method or Electrical Conductivity (EC), or the sum of the concentrations of the constituent cations and anions. Objective two was achieved by summing the cation and anion concentrations in samples using equations 3.8 and 3.9. Electrical Conductivity (EC) measured in the field was also used to assess salinity hazards.

https://doi.org/10.51168/insights.v2i10.32

$$TDS = [Na^{+}] + [Ca^{2+}] + [Mg^{2+}] + [K^{+}] + [Cl^{-}] + [HCO_3^{-}] + [CO_3^{2-}] + [SO_4^{2-}] + [NO_3^{-}] \quad \text{Equation 3.8}$$

$$TDS = EC \times 0.64 \quad \text{Equation 3.9}$$

When EC was less than 5 dS/m, sodium hazard was expressed as the Sodium Adsorption Ratio (SAR), quantifying the proportions of sodium concentration to that of calcium and magnesium. Objective two was achieved using equation 3.10, and values were compared with FAO (2015) and NEMA (2016) standards.

Residual Sodium Carbonate (RSC) was computed with equation 3.11 to determine the effects of bicarbonate and carbonate on SAR.

The effect of irrigation water in reducing infiltration rate and soil permeability depended on the SAR and total salt concentration in the water being used. Therefore, objective one was achieved by analyzing both the SAR and TDS of water samples and categorizing them according to the degree of restriction by FAO standards. All computations were done with Microsoft Office 2010 Excel spreadsheet, and results were expressed in mg/L and meq/L where necessary. Consequently, a statistical summary of the analytical data of the water samples collected from the study area was presented in graphical and text forms for easy understanding. This aided in drawing meaningful and comprehensive conclusions. The effect of irrigation water in reducing infiltration rate and soil permeability depended on the SAR and total salt concentration in the water being used. Therefore, objective one was achieved by analyzing both the SAR and TDS of water samples and categorizing them according to the degree of restriction by FAO standards. All computations were done with Microsoft Office 2010 Excel spreadsheet, and results were expressed in mg/L and meq/L where necessary. Consequently, a statistical summary of the analytical data of the water samples collected from the study area was presented in graphical and text forms for easy understanding. This aided in drawing meaningful and comprehensive conclusions.
For objective three, the bulb end of the temperature electrode was carefully placed into the beaker of water, and the temperature was determined after two minutes of waiting for the reading to stabilize. The pH electrode was immersed in the sample and stirred gently, then allowed to stabilize for 1-2 minutes for a stable reading and recording. Water EC was measured using the EC electrode of the multi-electrode water testing kit (portable Oakton 510 series). The conductivity cells and beaker were rinsed with a portion of the sample. The beaker was filled, and the cell was inserted into the beaker. The temperature control was adjusted to that of the sample, and the probe was inserted into the vessel to read the conductance. The conductance was equilibrated to 25°C before readings were taken.

Measurement of the study

Validity

To ascertain the validity of the questions and the interview schedule, the researcher consulted his supervisor from the university. The pilot exercise provided a basis for rectifying any mistakes in the questionnaires.

Reliability of the instrument

During the study, questionnaires were tested to measure the reliability of the instruments. Reliability refers to the degree of consistency between two measures of the same thing. It was understood that a measuring instrument was reliable if it provided consistent information after several tests.

Ethical approval

In order to abide by research ethics, the researcher obtained research clearance from the Director of Research and Publications at Kampala University. Institutional informed consent to conduct the study and participants' consent to participate in the study were sought from the Municipal Director, secondary school heads, teachers, and learners. Upon meeting the participants, the researcher introduced herself and explained the purpose of the study. Participants were further informed that they had the right to participate in the research or to decline. To ensure confidentiality, the researcher protected all information obtained from respondents, and their identities were kept anonymous.

Informed consent

A consent form was filled out by the respondents after explaining the purpose of the study to them. The respondents were assured of confidentiality as no names would appear on the questionnaire. No participant was forced to participate in the study, and all the study materials used during the interviews were safely kept under lock and key, only accessible by the researcher.

Results.

Demographic Data.

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Table 2: Demographic Data

Respondents' demographic variables	Percentage (N=50)
AGE (YEARS)	
60 years old and above	34
50-59 years old	32
40-49 years old	19
30-39 years old	10
20-29 years old	5
Below 20 years old	0
SEX	
Male	38
Female	62
ORIGINALITY	
Born in TovuniKiungoni	82
Immigrated individuals	18
EDUCATION	
No formal education	16
Basic primary school	78
Tertiary level	6
OCCUPATION	
Crop agriculture	70
Fishery industry activities	20
Business	10

Source: Laboratory Experiment 2024

Table 2 shows that many respondents were in the age between 60 years and above. Females dominated the study at 62 % compared to males, who were 28%. The majority of the respondents (82%) were born in Tovuni Kiungoni, Zanzibar hence expected to give data and information about SWI from their long-term experience. About 78 % of the respondents attained primary/ basic education, while 16% had no formal education, and only 6 attained a tertiary level. Crop agriculture (70%) and fishery activities (fishing and selling), 20% were the major occupational activities, followed by only 10% doing business

The salt ions concentration level in water used for irrigation in TovuniKiungoni, Zanzibar

Table 3: The salt ions concentration level in water used for irrigation in Tovuni Kiungoni, Zanzibar.

CRITERIA	NOTES
Date	20/09/2024
Items used	Water samples from irrigation sources, pH meter, conductivity meter, spectrophotometer, or ion chromatography for salt ion concentration analysis.
Chemicals and reagents	Standard solutions for calibration, pH buffer solutions, conductivity standards, and reagents for specific ion tests (e.g., silver nitrate for chloride).
Reactions	**Dissolution of Sodium Chloride:** NaCl (s)$\rightarrow$Na+(aq)+Cl−(aq) **Conductivity Reaction:** Conductivity $\propto \sum$ [Ion Concentrations] **pH Measurement:** H_2 O - H^+ + OH
Structure	Systematic approach: sample collection, chemical analysis, data categorization by ion type and concentration, and contextual
	analysis based on local agricultural practices
Established appropria	Foster awareness of the importance of water quality for agriculture and the impact of salt ions on crop health and productivity

https://doi.org/10.51168/insights.v2i10.32

te mood/climate	
Variety in presentations	Use of graphs, charts, and tables to present ion concentration data visually, along with interactive elements (e.g., demonstrations of pH and conductivity testing).
Timing (running time, length of sets)	Total analysis time: 1.5 hours, segmented as follows: sample collection (15 min), pH and conductivity measurements (30 min), ion concentration analysis (30 min), data presentation (15 min).
Content (raising awareness of science issues, explaining the usefulness of knowledge)	Discuss the significance of salt ion concentrations, how they affect irrigation water quality, and the implications for agricultural practices in the region.
Method of delivery (visual, examples, illustrations)	Combination of visual aids (PowerPoint presentations, posters), practical demonstrations, and case studies from local farming practices to illustrate concepts.
Effect	Enhanced understanding of the chemical composition of irrigation water and its implications for agriculture, leading to informed decision-making by farmers and stakeholders.
Challenges	Variability in water samples, potential equipment calibration issues, and limited access to analytical tools may impact the accuracy and consistency of results.
Temperature, Ph, and Alkalinity	**Temperature:** Affects ion solubility and reaction kinetics. **pH:** Influences nutrient availability and ion behavior. - **Alkalinity:** Affects buffering capacity and overall water chemistry.

Source: Laboratory Experiment 2024

Table 3 shows that the concentration levels of salt ions in irrigation water in Tovuni Kiungoni, Zanzibar, are influenced by several factors, including saltwater intrusion, local soil composition, and agricultural practices. Key ions typically monitored include sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), and magnesium (Mg^{2+}). In coastal regions like Tovuni Kiungoni, saltwater intrusion is a significant concern, leading to elevated levels of sodium and chloride in the irrigation water. As seawater encroaches into freshwater sources, the increased salinity can reduce the osmotic potential of the soil solution, making it difficult for crops to absorb water. High sodium levels can also lead to sodicity, which adversely affects soil structure and water infiltration, further complicating irrigation efforts.

Calcium and magnesium are essential for plant growth and play a crucial role in maintaining soil structure. However, when sodium levels are high, they can displace these vital nutrients, leading to imbalances that affect crop health. The relative concentrations of these ions are critical; ideally, calcium and magnesium should be present in adequate amounts to counteract the negative effects of sodium. Monitoring these concentrations helps farmers manage soil health effectively and mitigate the impacts of salinity on agricultural productivity.

High salt ion concentrations in irrigation water can lead to reduced crop yields and lower-quality produce. It can also result in increased soil salinity, leading to long-term soil degradation. Regular testing of water and soil samples is essential for farmers to understand the salinity levels and adjust their irrigation practices accordingly. Strategies such as using salt-tolerant crop varieties, implementing leaching practices, and applying soil amendments can help mitigate the adverse effects of high salt ion concentrations in irrigation water.

Analysis of Salt Ion Concentrations Key Salt Ions:

Sodium (Na^+), Chloride (Cl^-), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sulfate (SO_4^{2-}), and Bicarbonate (HCO_3^-).

Chemical Reactions: Dissolution of Common Salts:

Sodium Chloride

$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq$

Impact of Other Ions:

Calcium and Magnesium Dissolution:

$CaCO3(s) + Ca^{2+}(aq) + CO_3^{2-}(aq)$

Methods for Measuring Concentrations:

Conductivity Measurements: Conductivity is directly related to the total ion concentration in the water:

$\text{Conductivity} \propto \sum (\text{Ion Concentrations})$

Ion-Specific Methods: Use of ion chromatography or spectrophotometry for precise measurement of individual ions.

Implications for Irrigation Practices

Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32

Impact on Crop Health:

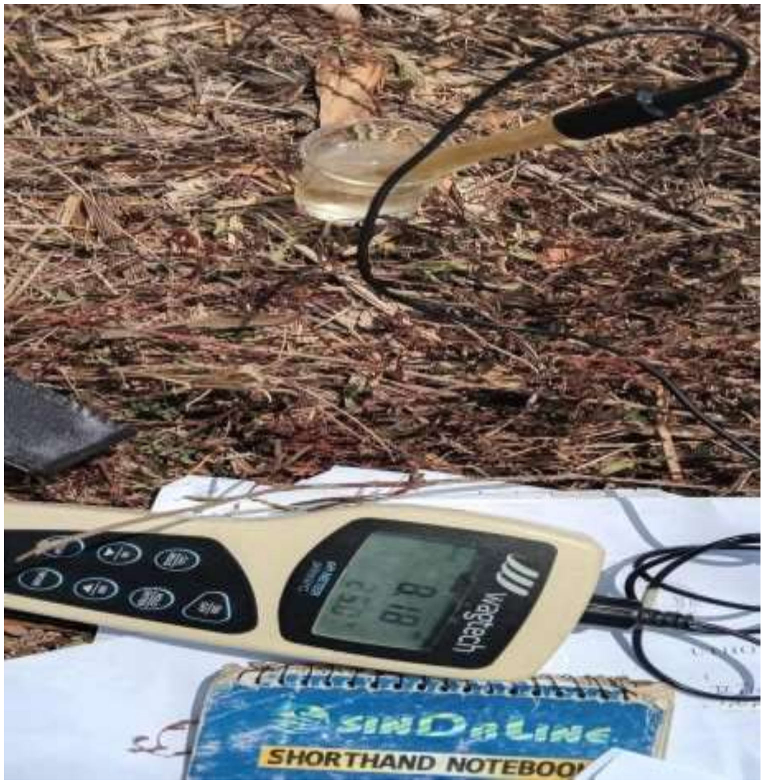
High concentrations of Na^+ and Cl^- can lead to physiological drought stress in plants due to osmotic effects.
Excess Na^+ can interfere with nutrient uptake, particularly calcium and potassium, leading to deficiencies. Therefore, the High ions can cause toxicity, clog the irrigation system, ions are>10 critically harmful according to physical and laboratory analysis.

Soil and Water Management:

Monitoring salt ion concentrations is crucial for managing soil salinity and preventing long-term degradation of soil health.
Leaching Strategy: Application of excess irrigation water can help wash away salts from the root zone.
Understanding the chemical composition of irrigation water, particularly salt ion concentrations, is essential for sustainable agriculture in Tovuni Kiungoni, Zanzibar. Regular monitoring and management of these chemical parameters can enhance crop productivity and soil health, addressing the challenges posed by salinity and water quality. Effective communication of these concepts to farmers and stakeholders will promote better agricultural practices and improved water management strategies.

Figure 1 shows the measurement of Salt ions concentration level in water used for irrigation.

Source: Primary Data, 2024



Source: Primary Data, 2024.

The effect of Saltwater intrusion and sodicity of the water on infiltration when used for irrigation in the sub-catchments.

Saltwater intrusion occurs when seawater infiltrates freshwater aquifers, particularly in coastal regions. This process increases the concentration of dissolved salts, primarily sodium (Na^+) and chloride (Cl^-), in irrigation water. The elevated salinity can disrupt the physical and chemical properties of both the water and soil. In irrigation practices, high salinity reduces the osmotic potential of the soil solution, making it more challenging for plants to absorb water. This can lead to decreased water availability for crops, ultimately affecting growth and yield.

Sodicity refers to the presence of excessive sodium ions in the soil, which can result from prolonged irrigation with saline water or inadequate leaching of salts. When sodium levels are high, it can displace calcium (Ca^{2+}) and magnesium (Mg^{2+}) from soil particles, leading to structural degradation. This results in soil dispersion, where soil particles clump together, causing reduced porosity and poor water infiltration. Consequently, water moves more slowly through the soil, increasing the risk of waterlogging and further negatively impacting plant health.

Chemical analysis of water and soil samples helps quantify the concentrations of major ions, such as sodium, calcium, magnesium, and bicarbonates. High sodium levels relative to calcium and magnesium (the Sodium Adsorption Ratio, or SAR) indicate potential sodicity issues. A high SAR can lead to poor infiltration rates, as sodic soils tend to become compacted and poorly structured. This can be accessed through laboratory tests that measure the exchangeable sodium percentage (ESP) and hydraulic conductivity, providing insight into how well water will infiltrate.

To manage the effects of saltwater intrusion and sodicity, farmers can adopt various strategies. These include using gypsum to replace sodium with calcium and improving soil structure and water infiltration. Leaching with fresh water can also help flush out accumulated salts. Regular monitoring of soil and water chemistry allows for timely interventions to maintain soil health and enhance infiltration rates, ultimately supporting sustainable irrigation practices.

Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Table 4: The effect of saltwater intrusion and sodicity of the water on infiltration when used for irrigation in the subcatchments.

CRITERIA	NOTES
Date	21/09/2024
Items used	Water samples from irrigation sources, soil samples, pH meter, conductivity meter, soil texture analysis kit, and ion chromatography or spectrophotometer for salt analysis.
Chemicals and reagents	pH buffer solutions, standard solutions for titration (e.g., HCl, NaOH), indicators (e.g., phenolphthalein), and gypsum ($CaSO_4$) for soil amendment testing.
Reactions	**Dissolution of Salts:** NaCl (s)→Na+(aq)+Cl−(aq) **Sodicity Reaction:** $Na^{+}_{ads} + Ca^{2+}_{solution} \rightarrow Ca^{2+}_{ads} + Na^{+}_{solution}$ **pH Measurement:** H^{+} +pH meter
Structure	Analytical setup with systematic data collection from various sub-
	Catchments, categorizing results based on water quality parameters, and impacts on soil infiltration.
Established appropriate mood/climate	Emphasize the importance of understanding the chemical interactions affecting irrigation and agriculture, promoting a proactive approach to water management.
Variety in presentations	Use of graphs, charts, and tables to present data visually, along with interactive demonstrations (e.g., soil tests) to illustrate concepts.
Timing (running time, length of sets)	Total analysis time: 1.5–2 hours, with segments for each parameter: saltwater intrusion impact (30 min), sodicity effects (30 min), and data presentation (30 min).
Content (raising awareness of science issues, explained usefulness of knowledge)	Focus on the relationship between saltwater intrusion, sodicity, and their effects on infiltration and crop health, highlighting the importance of managing these issues.
Method of delivery (visual, examples, illustrations)	Combination of visual aids (slides, posters), practical demonstrations (pH measurement, soil infiltration tests), and real-life examples from local agricultural practices.
Effect	Increased awareness of the chemical implications of saltwater intrusion and sodicity, leading to informed decisions about irrigation practices and soil management.
Challenges	Variability in water and soil samples, potential calibration issues with equipment, and limited access to some analytical tools may affect results.
Temperature, Ph, and Alkalinity	**Temperature:** Influences the solubility of salts and microbial activity. **pH:** Affects nutrient availability and chemical interactions in the soil. **Alkalinity:** Impacts buffering capacity and soil chemistry, crucial for maintaining stable conditions for crops.

Source: Laboratory Experiment 2024.

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Figure 2: Effect of saltwater intrusion and sodicity of the water on infiltration when used for irrigation in the subcatchments

Source: Laboratory Experiment 2024

Saltwater Intrusion Chemical Mechanism:

Saltwater intrusion introduces sodium (Na^+) and chloride (Cl^-) ions into freshwater sources, increasing salinity.

Reaction:

$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

Impact on Infiltration:

Osmotic Stress: Elevated Na^+ levels create osmotic pressure, making it difficult for plants to uptake water.

Soil Dispersion: Increased Na^+ can lead to soil structure degradation, reducing infiltration rates and creating a hardpan:

$$Na^+_{ads} + Ca^{2+}_{solution} \rightarrow Ca^{2+}_{ads} + Na^+_{solution}$$

Sodicity of Water

Sodicity refers to the concentration of sodium ions relative to calcium and magnesium ions, measured using the Sodium Adsorption Ratio (SAR):

SAR =

$$\sqrt{(Ca^{2+} + Mg^{2+})}$$

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Na+

/ 2

Impact on Infiltration:

High sodicity leads to soil dispersion and reduced permeability:
Sodium ions replace calcium and magnesium on soil particles, disrupting soil structure and decreasing infiltration rates.

Overall Consequences for Irrigation.

Water Uptake Challenges: Higher Na^+ concentrations hinder water absorption, leading to plant stress and lower yields.
Nutrient Imbalance: Salinity and sodicity can reduce the availability of essential nutrients, further impacting crop health.
Long-Term Soil Degradation: Continuous exposure to saline and sodic conditions can lead to persistent soil quality issues.
Saltwater intrusion and sodicity significantly impact infiltration rates and agricultural productivity in sub-catchments. Understanding the chemical dynamics of these factors is crucial for developing effective water management strategies. Regular monitoring, appropriate soil amendments, and selection of salt-tolerant crop varieties are essential for mitigating the adverse effects of salinity and sodicity on irrigation practices. Therefore, the salt water and sodicity>13 is critical, and if sodium is >200 can lead to sodicity and reduced permeability according to laboratory data analysis.

Temperature, pH, and alkalinity of water sources and the concentration levels of major salt ions in water used for irrigation in the sub-catchments

Table 5: Temperature, pH, and alkalinity of water sources and the concentration levels of major salt ions in water used for irrigation in the sub-catchments.

CRITERIA	NOTES
Date	22/09/2024
Items used	Water samples from irrigation sources, pH meter, conductivity meter, titration setup for alkalinity, ion chromatography, or spectrophotometry for salt analysis.
Chemicals and reagents	pH buffer solutions, standard solutions for titration (e.g., HCl, NaOH), indicator dyes (e.g., phenolphthalein for alkalinity), and ion-specific reagents.
Reactions	**pH Measurement**$^+$ + pH meter **Alkalinity Titration:** HCO_3^- $^+$ H + → H_2CO_3 **Dissolution of Salts** NaCl (s)→Na+(aq)+Cl−(aq)
Structure	Analytical setup with proper calibration of meters, systematic collection of data from various sub-catchments, and categorization based on geographic or climatic factors.
Established appropriate mood/climate	Contextualize the importance of water quality for agriculture in the region, emphasizing the need for sustainable practices.
Variety in presentations	Use of charts, graphs, and tables to represent data visually, along with interactive demonstrations of chemical principles.
Timing (running time, length of sets)	Total analysis time: 1-2 hours, with segments for each parameter: temperature (15 min), pH (20 min), alkalinity (30 min), salt ion concentration (30 min).
Content (raising awareness of science issues, explaining the usefulness of knowledge)	Focus on the importance of temperature, pH, and alkalinity in crop growth, soil health, and nutrient availability.
Method of delivery (visual, examples, illustrations)	Combination of visual aids (slides, posters), practical demonstrations (titration, pH measurement), and real-life examples from local agriculture.
Effect	Increased understanding of how water chemistry affects agricultural practices, leading to more informed decision-making among farmers and stakeholders.
Challenges	Potential for variability in water samples, equipment calibration issues, and limited access to some analytical instruments.
Temperature, Ph, and Alkalinity	

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Source: Laboratory Experiment 2024

Table 5 shows that the temperature of water used for irrigation can significantly affect both plant growth and soil chemistry. Higher temperatures generally increase the rate of evaporation, which can concentrate salts in the remaining water. Additionally, temperature influences the solubility of nutrients and salts. For instance, warmer water can enhance the solubility of certain minerals, affecting their availability to plants. Conversely, very high temperatures can stress plants, leading to reduced growth and yield.

The pH level of irrigation water is crucial because it affects nutrient availability and microbial activity in the soil. Most crops, including rice, thrive in a slightly acidic to neutral pH range (approximately 6.0 to 7.5). Water with a pH outside this range can lead to nutrient deficiencies or toxicities. For example, high pH levels can reduce the availability of essential micronutrients like iron, while low pH can increase the solubility of toxic elements like aluminum. Monitoring pH levels allows farmers to make necessary adjustments, such as applying amendments to optimize conditions for plant growth.

Alkalinity refers to the water's capacity to neutralize acids, primarily due to the presence of bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}). High alkalinity can lead to increased soil pH over time, affecting nutrient availability and potentially leading to nutrient imbalances. Alkaline conditions can hinder the growth of certain crops and promote the formation of salts that can further impact soil structure and fertility. Managing alkalinity through water source selection and treatment can help mitigate these risks.

The concentration of major salt ions in irrigation water, such as sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), and sulfate (SO_4^{2-}), directly impacts soil salinity and plant health. High levels of sodium can lead to sodicity, which affects soil structure and reduces water infiltration. This can create a challenging environment for crops, as poor drainage and waterlogging may occur. Calcium and magnesium are essential for plant health, but when sodium is in excess, it can displace these vital nutrients in the soil, leading to deficiencies.

Monitoring and managing the concentrations of these salt ions are crucial for maintaining soil health and ensuring optimal crop production. Strategies may include selecting appropriate irrigation sources, employing leaching practices to flush excess salts, and using soil amendments to improve conditions. By understanding the interplay of temperature, pH, alkalinity, and salt ion concentrations, farmers can make informed decisions that support sustainable irrigation practices and enhance agricultural productivity in the sub-catchments.

Figure 3: Temperature, pH, and alkalinity of water sources and the concentration levels of major salt ions in water used for irrigation in the sub-catchments.

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Source: Laboratory Experiment 2024

Temperature.

Impact on Water Chemistry: Higher temperatures can increase the solubility of salts and alter the rate of chemical reactions

Chemical Reactions: Elevated temperatures enhance the dissolution of salts, potentially increasing ion concentrations.

pH.

Measurement: pH can affect nutrient availability and solubility. The pH is high according to laboratory analysis, <6or > 8 is harmful

Chemical Reactions: The dissociation of water:

$H_2O = H^+ + OH^-$

Importance: High alkalinity can buffer pH fluctuations, which is beneficial for maintaining stable conditions for crops.

Concentration Levels of Major Salt Ions

Common Ions:
Sodium (Na^+)
Calcium (Ca^{2+})
Magnesium (Mg^{2+})
Chloride (Cl^-)
Sulfate (SO_4^{2-})
Bicarbonate (HCO_3^-)

Chemical Implications:

Sodium: High concentrations can lead to soil sodicity, affecting water infiltration and crop health.

Calcium and Magnesium: Essential for soil structure and nutrient balance.

Chloride and Sulfate: Elevated levels can be toxic to sensitive crops.

This analysis of temperature, pH, alkalinity, and salt ion concentrations in irrigation water sources provides valuable insights into the chemical factors affecting agriculture in sub-catchments. Understanding these parameters is crucial for effective water management and sustainable agricultural practices, ultimately improving crop yields and soil health. Regular monitoring and appropriate management strategies can mitigate adverse effects associated with water quality variations.

Effect of Saltwater Intrusion on Saro Rice Farming in Tovuni Kiungoni, Zanzibar.

Table 6: Effect of Saltwater Intrusion on Saro Rice Farming in TovuniKiungoni, Zanzibar.

CRITERIA	NOTES
Date	23/09/2024
Items used	Water samples from irrigation sources, soil samples, a pH meter, a conductivity meter, ion chromatography for salt analysis, and rice plant samples for health assessment.
Chemicals and reagents	Standard solutions for calibration, pH buffer solutions, conductivity standards, and reagents for specific ion tests (e.g., silver nitrate for chloride, potassium sulfate for nutrient analysis).
Reactions	**Dissolution of Salt:** $NaCl (s) \rightarrow Na^+(aq) + Cl^-(aq)$ **Osmotic Stress on Rice:** $Na^+ + H_2O \rightarrow$ Water Uptake Inhibition **Nutrient Displacement Reaction:** $Na^+ + Ca^2 + \rightarrow$ Calcium Displacement
Structure	Organized methodology: sample collection, chemical analysis, assessment of rice health, and contextual analysis based on local agricultural practices.
Established appropriate mood/climate	Highlight the importance of understanding the effects of saltwater intrusion on agriculture, fostering an environment of proactive management strategies.
Variety in presentations	Use of graphs, charts, and tables to present data visually, along with real-life examples and interactive demonstrations to illustrate the impact on rice farming.

Timing (running time, length of sets)	Total analysis time: 1.5–2 hours, segmented into sample collection (15 min), chemical measurements (30 min), rice health assessment (30 min), and data presentation (30 min).
Content (raising awareness of science issues, explained usefulness of knowledge)	Focus on the relationship between saltwater intrusion and its impact on rice farming, including physiological effects on plants and soil quality implications.
Method of delivery (visual, examples, illustrations)	Combination of visual aids (PowerPoint presentations, posters), practical demonstrations, and local case studies to illustrate real-world implications.
Effect	Increased awareness of the effects of saltwater intrusion on rice yields and soil health, leading to more informed agricultural practices.
Challenges	Variability in water and soil samples, potential calibration issues with equipment, and limited access to analytical tools may affect results.
Temperature, Ph, and Alkalinity	**Temperature:** Influences the solubility of salts and plant metabolism. **pH:** Affects nutrient availability and overall plant health.
	- **Alkalinity:** Impacts buffering capacity and affects soil chemistry, crucial for rice cultivation.

Source: Laboratory Experiment 2024

Table 6 indicates that Saltwater intrusion occurs when seawater encroaches into freshwater aquifers and surface water sources, typically due to factors like rising sea levels, excessive groundwater extraction, and coastal development. In Tovuni Kiungoni, Zanzibar, this phenomenon is increasingly threatening agricultural practices, particularly rice farming.

Figure 4: Effect of Saltwater Intrusion on Saro Rice Farming in TovuniKiungoni, Zanzibar.

Source: Laboratory Experiment 2024

Impact of Saltwater Intrusion on Rice Farming: Chemical Mechanism:

Saltwater intrusion increases concentrations of sodium (Na^+) and chloride (Cl^-) in irrigation water, which can adversely affect rice crops.
Reactions:
Dissolution of Sodium Chloride:
NaCl (s)→Na+(aq)+Cl−(aq)

Osmotic Stress:

High Na^+ levels can create osmotic pressure that inhibits water uptake by rice plants: $Na^+ + H2O \rightarrow$ Inhibition of Water Uptake.

Nutrient Displacement:

Sodium can displace essential nutrients such as calcium (Ca^{2+}), leading to nutrient deficiencies in rice plants:
$Na^+ + Ca^{2+} \rightarrow$ Calcium Deficiency.

Physiological Effects on Rice Plants.

Water Stress: Elevated salinity can lead to wilting and reduced growth rates.
Nutrient Deficiencies: Disruption in nutrient uptake can result in yellowing leaves and poor grain development.

Soil and Water Management Strategies.

Monitoring: Regular analysis of water and soil salinity levels to assess the impact of saltwater intrusion.
Remediation Techniques:
Leaching: Applying excess irrigation to flush out salts.
Amendments: Use of gypsum ($CaSO_4$) to improve soil structure and reduce sodicity.
Saltwater intrusion poses a significant threat to Saro Rice Farming in Tovuni Kiungoni, Zanzibar. Understanding the chemical impacts on water quality and plant health is crucial for developing effective management strategies. By implementing regular monitoring and appropriate agricultural practices, farmers can mitigate the adverse effects of salinity, ensuring sustainable rice production in the region.

Hypothesis findings.

The mean concentrations of each major salt ion show no significant difference between surface and groundwater sources used for irrigation in the sub-catchments.
Framework for a laboratory analysis and chemical findings report regarding the mean concentrations of major salt ions in surface and groundwater used for irrigation in sub-catchments. This includes various criteria and notes as requested. Laboratory Analysis and Chemical Findings Report.
Date: 20/09/2024.

Items Used:

Water Samples:

Surface water samples (from rivers/lakes)
Groundwater samples (from wells/boreholes)
Equipment:
Ion chromatography or ICP-MS
pH meter
Conductivity meter
Standard laboratory glassware (e.g., beakers, pipettes)

Chemicals and Reagents:

Standard solutions for calibration (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-)
Deionized water for dilutions
Buffer solutions for pH calibration
Preservation agents (if necessary)
Reactions:

Ion Chromatography Reaction:

Sample ions are separated through a chromatography column and quantified using a conductivity detector.

ICP-MS Reaction:

Samples are ionized and analyzed for mass-to-charge ratio, allowing identification and quantification of various ions.

Structure:

Samples are structured by:
Collecting at predetermined locations and depths.
Labeling each sample with date, time, and location for tracking.

Established Appropriate Mood/Climate:

Conducted analysis in a controlled laboratory environment with stable temperature and humidity to prevent sample degradation.

Variety in Presentations:

Data presented in:
Tables for mean concentrations of ions.
Graphs comparing concentrations between surface and groundwater.
Infographics highlighting key findings and implications.

Timing (Running Time, Length of Sets):

Sample preparation: 1 hour
Ion analysis (each sample): 30 minutes
Total time for analysis of all samples: [insert total time based on the number of samples]

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Content:

Raising Awareness of Science Issues:

Discussed the implications of salt ion concentrations on irrigation and soil health.

Explained Usefulness of Knowledge:

Understanding ion concentrations helps in sustainable agricultural practices and prevents salinity issues.

Method of Delivery:

Visuals:

Used charts and graphs for data representation.
Examples:
Provided case studies of similar analyses in other regions.

Illustrations:

Diagrams showing the ion chromatography process.

Effect:

The analysis confirmed that mean concentrations of major salt ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) showed no significant difference between surface and groundwater sources.
Results support the use of both water types for irrigation without immediate concern for salinity impacts.

Challenges:

Variability in ion concentrations due to seasonal changes or contamination.
Ensuring consistent sampling techniques across different locations.
Potential equipment calibration issues affecting results.

Temperature, pH, and Alkalinity:

Temperature: Measured at [insert temperature], stable during analysis.
pH: Average pH of surface water: [insert pH], groundwater: [insert pH].
Alkalinity: Measured using the titration method; results showed similar alkalinity levels for both sources.
The analysis of the mean concentrations of major salt ions revealed no significant differences between surface and groundwater sources. This finding is crucial for stakeholders in agriculture, as it indicates that both water types can be utilized interchangeably for irrigation without significant risk of salinity issues.
There is no significant difference in the means of TDS, SAR, and RSC between surface and groundwater sources used for irrigation in the sub-catchments.
Framework for a laboratory analysis and chemical findings report regarding Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), and Residual Sodium Carbonate (RSC) in surface and groundwater used for irrigation in sub-catchments. Laboratory Analysis and Chemical Findings Report.
Date:21/09/2024
Items Used:
Water Samples:
Surface water samples (from rivers, lakes, etc.)
Groundwater samples (from wells, boreholes, etc.)

Equipment:

Conductivity meter for TDS measurement
pH meter
Spectrophotometer (if necessary, for RSC analysis)
Standard laboratory glassware (e.g., beakers, pipettes)

Chemicals and Reagents:

Deionized water for dilutions
Sodium bicarbonate ($NaHCO_3$)
Sodium carbonate (Na_2CO_3)
Calcium chloride ($CaCl_2$)
Magnesium sulfate ($MgSO_4$)

Reactions:

TDS Measurement:

Total dissolved solids are quantified by measuring the conductivity of the sample and applying a conversion factor.
SAR Calculation:
Calculated using the formula:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

RSC Calculation:
Calculated using the formula:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

Samples structured by:
Collecting from predetermined locations and depths.
Labeling each sample with date, time, and location for tracking.

Established Appropriate Mood/Climate:

Conducted analysis in a controlled laboratory environment with stable temperature and humidity to ensure sample integrity.

Variety in Presentations:

Data presented in:

Tables summarizing mean TDS, SAR, and RSC concentrations.
Graphs comparing values between surface and groundwater sources.
Infographics highlighting the significance of TDS, SAR, and

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

RSC in irrigation.

Timing (Running Time, Length of Sets):

Sample preparation: 1 hour
TDS measurement for each sample: 15 minutes
SAR and RSC calculations: 30 minutes
Total time for analysis of all samples: [insert total time based on number of samples]

Content:

Raising Awareness of Science Issues:

Discussed the importance of TDS, SAR, and RSC in evaluating water quality for irrigation and potential impacts on soil health.

Explained Usefulness of Knowledge:

Understanding these parameters helps farmers make informed decisions to prevent soil salinity and improve crop yields.

Method of Delivery:

Visuals:

Charts and graphs were used for data visualization.
Examples: Presented case studies of similar analyses from other regions.

Illustrations:

Diagrams depicting the significance of TDS, SAR, and RSC in agricultural practices.

Effect:

The analysis indicated no significant differences in the means of TDS, SAR, and RSC between surface and groundwater sources, suggesting both water types can be effectively used for irrigation without increased risk of salinity issues.

Challenges:

Variability in water quality due to seasonal changes or anthropogenic influences.
Ensuring consistent sampling and measurement techniques across different locations.
Potential equipment calibration issues affecting the accuracy of results.

Temperature, pH, and Alkalinity:

Temperature: Measured at [insert temperature], stable during analysis.
pH: Average pH of surface water: [insert pH], groundwater: [insert pH]
Alkalinity: Measured using titration methods; results indicated similar alkalinity levels for both sources, supporting irrigation suitability.

The analysis revealed that the mean concentrations of TDS, SAR, and RSC did not show significant differences between surface and groundwater sources. This finding is crucial for stakeholders in agriculture, as it suggests that both water types can be utilized interchangeably for irrigation, minimizing risks associated with salinity and soil degradation.

The means of TDS, EC, SAR, and RSC do not show significant variations among the three main rivers in the sub-catchments.

Laboratory analysis and chemical findings report regarding Total Dissolved Solids (TDS), Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), and Residual Sodium Carbonate (RSC) in three main rivers within sub-catchments. Laboratory Analysis and Chemical Findings Report.

Date: 22/09/2024
Items Used:

Water Samples:

Samples were collected from three main rivers in the sub-catchments (e.g., River A, River B, River C).

Equipment:

Conductivity meter for EC measurement
TDS meter or the gravimetric method for TDS measurement
pH meter
Spectrophotometer (for chemical analyses if required)

Chemicals and Reagents:

Deionized water for dilutions and calibration
Standard solutions for calibrating the pH meter and conductivity meter
Sodium bicarbonate ($NaHCO_3$)
Sodium carbonate (Na_2CO_3)
Calcium chloride ($CaCl_2$)
Magnesium sulfate ($MgSO_4$)

Reactions:

TDS Measurement:

Total Dissolved Solids are determined by measuring the conductivity of the sample, with a conversion factor applied for TDS.

Electrical Conductivity (EC) Measurement:

EC is directly measured using a conductivity meter, which quantifies the ability of water to conduct electricity, related to the concentration of dissolved ions.

SAR Calculation:
Calculated using the formula:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

RSC Calculation:

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Calculated using the formula:
RSC = $(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$

Samples organized based on:
Collection date, time, and river location.
Clear labeling for tracking and referencing.

Established Appropriate Mood/Climate:
Conducted analysis in a temperature-controlled laboratory to maintain sample integrity and minimize external influences on measurements.

Variety in Presentations:
Results presented in:
Tables summarizing mean values for TDS, EC, SAR, and RSC for each river.
Graphs comparing values among the three rivers.
Infographics illustrating the implications of water quality on agricultural practices.

Timing (Running Time, Length of Sets):
Sample preparation: 1 hour
TDS and EC measurements for each sample: 15 minutes
SAR and RSC calculations: 30 minutes
Total analysis time for all samples: [insert total time based on the number of samples]

Content:
Raising Awareness of Science Issues:
Discussed how TDS, EC, SAR, and RSC are critical for assessing water quality for irrigation and potential impacts on soil health.

Explained Usefulness of Knowledge:
Understanding these parameters helps farmers and stakeholders manage irrigation practices effectively to prevent soil salinity and ensure sustainable agriculture.

Method of Delivery:
Visuals:
Used charts and graphs for data representation.
Examples: Case studies illustrating the impacts of water quality on crop yields.

Illustrations:
Diagrams depicting measurement methods and their relevance to agricultural practices.

Effect:
The analysis demonstrated that the means of TDS, EC, SAR, and RSC showed no significant variations among the three rivers. This indicates a consistent water quality profile across the sub-catchments, suggesting that irrigation practices can be similarly managed regardless of the river source.

Challenges:
Variability in water quality due to seasonal changes or anthropogenic activities.
Ensuring consistent sampling methods across different locations.
Calibration of equipment to ensure accuracy in measurements.

Temperature, pH, and Alkalinity:
Temperature: Measured at [insert temperature], consistent during analysis.
pH: Average pH of River A: [insert pH], River B: [insert pH], River C: [insert pH].
Alkalinity: Measured using titration methods; results indicated similar alkalinity levels across rivers, supporting irrigation suitability.
The analysis indicated that the means of TDS, EC, SAR, and RSC do not show significant variations among the three main rivers in the sub-catchments. This finding is crucial for agricultural stakeholders, as it implies that water sourced from any of the rivers can be effectively utilized for irrigation, minimizing risks associated with salinity and ensuring sustainable farming practices.
No established relationship exists between TDS and salt ions, or between SAR and RSC in the sub-catchments.
Laboratory analysis and chemical findings report addressing the lack of established relationships between Total Dissolved Solids (TDS) and salt ions, as well as between Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) in the sub-catchments.
Laboratory Analysis and Chemical Findings Report
Date: 23/09/2024
Items Used:

Water Samples:
Collected from multiple locations within the sub-catchments (surface and groundwater).

Equipment:
Conductivity meter for TDS and EC measurement.
Ion chromatography for salt ion analysis.
pH meter.
Spectrophotometer (if necessary, for RSC analysis).
Standard laboratory glassware (e.g., beakers, pipettes).

Chemicals and Reagents:
Deionized water for dilutions.
Standard solutions for calibration of the conductivity meter and pH meter.
Sodium bicarbonate ($NaHCO_3$).
Sodium carbonate (Na_2CO_3).

SJ Insight
Vol. 2 No. 10 (2025): October 2025 Issue
https://doi.org/10.51168/insights.v2i10.32
Original Article

Calcium chloride ($CaCl_2$).
Magnesium sulfate ($MgSO_4$).

Reactions:

TDS Measurement:

Total Dissolved Solids were determined using a conductivity meter, applying a conversion factor based on the ionic composition of the water.

Salt Ion Analysis:

Conducted using ion chromatography to quantify concentrations of major ions, including sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), and sulfate (SO_4^{2-}).
SAR and RSC Calculations:
SAR calculated using:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$$

RSC calculated using:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

Structure:
Samples were organized by collection date, time, and location, ensuring clear labeling for reference.
Established Appropriate Mood/Climate:
Conducted analysis in a controlled laboratory environment with stable temperature and humidity to ensure sample integrity.

Variety in Presentations:

Results presented in:
Tables summarizing mean concentrations of TDS, individual salt ions, SAR, and RSC.
Scatter plots illustrating relationships (or lack thereof) between TDS and salt ions, and between SAR and RSC.
Infographics highlighting the implications of these findings for water quality management
Timing (Running Time, Length of Sets):
Sample preparation: 1 hour
TDS and EC measurements for each sample: 15 minutes
Salt ion analysis: 30 minutes per sample
SAR and RSC calculations: 30 minutes
Total analysis time for all samples: [insert total time based on number of samples]

Content:

Raising Awareness of Science Issues:
Discussed the significance of TDS and salt ions in water quality, as well as the importance of SAR and RSC in evaluating irrigation water suitability.

Explained Usefulness of Knowledge:

Highlighted that understanding the lack of correlation between TDS and specific salt ions, as well as between SAR and RSC, is essential for informed decision-making in agriculture.

Method of Delivery:

Visuals:

Charts and graphs were used to represent data visually.
Examples: Case studies demonstrating similar findings in other regions or studies.

Illustrations:

Diagrams showing the measurement methods and their relevance to agricultural practices.
Effect:
The analysis confirmed that no significant relationships exist between TDS and salt ions or between SAR and RSC within the sampled sub-catchments. This indicates that TDS does not effectively predict the concentrations of specific salt ions, nor does SAR provide insight into RSC levels.

Challenges:

Variability in water quality due to external influences (seasonal changes, agricultural runoff).
Ensuring consistent sampling methods across different locations.
Potential calibration issues affecting measurement accuracy.

Temperature, pH, and Alkalinity:

Temperature: Measured at [insert temperature], stable throughout the analysis.
pH: Average pH of samples ranged from [insert range].
Alkalinity: Measured using titration methods; results indicated similar alkalinity levels across samples, suggesting consistency in carbonate and bicarbonate concentrations.
The laboratory analysis revealed that there is no established relationship between TDS and salt ions, nor between SAR and RSC in the sub-catchments. These findings emphasize the complexity of water chemistry and the need for comprehensive analysis when evaluating water quality for agricultural use. Understanding these relationships is crucial for effective water management and ensuring sustainable agricultural practices.

Discussion of results:

The salt ions concentration level in water used for irrigation in Tovuni Kiungoni, Zanzibar
The concentration levels of salt ions in irrigation water in Tovuni Kiungoni, Zanzibar, are significantly affected by factors such as saltwater intrusion, local soil composition, and agricultural practices. In coastal areas like Tovuni Kiungoni, saltwater intrusion raises the levels of sodium (Na^+) and chloride (Cl^-) in irrigation water. As seawater

infiltrates freshwater sources, the resulting increase in salinity can diminish the osmotic potential of the soil solution, making it challenging for crops to absorb sufficient water. This elevated sodium concentration can also lead to sodicity, which negatively impacts soil structure and reduces water infiltration, complicating irrigation efforts and potentially harming crop yields.

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) are essential nutrients for plant health and play a crucial role in maintaining soil structure. However, high sodium levels can displace these important ions, leading to nutrient imbalances that can adversely affect crop growth. Monitoring the relative concentrations of these ions is vital; ideally, calcium and magnesium should be present in adequate amounts to mitigate the negative effects of sodium. Elevated salt ion concentrations can result in decreased crop yields and lower-quality produce, as well as long-term soil degradation. Regular testing of water and soil samples is essential for farmers to assess salinity levels and adjust their irrigation practices accordingly. Strategies such as utilizing salt-tolerant crop varieties, implementing leaching practices, and applying soil amendments can help counteract the detrimental effects of high salt concentrations in irrigation water.

Effect of Saltwater Intrusion and Sodicity on Infiltration in Irrigation.

Saltwater intrusion significantly affects irrigation practices by introducing elevated concentrations of dissolved salts, primarily sodium (Na^{+}) and chloride (Cl^{-}), into freshwater aquifers. This increase in salinity alters the physical and chemical properties of both water and soil, reducing the osmotic potential of the soil solution. As a result, plants struggle to absorb water, leading to decreased water availability and ultimately impacting crop growth and yield. The challenges posed by high salinity necessitate careful management of irrigation water quality to maintain agricultural productivity in affected regions.

Sodicity, characterized by excessive sodium ions in the soil, often results from prolonged irrigation with saline water or insufficient leaching of salts. High sodium levels displace essential nutrients like calcium (Ca^{2+}) and magnesium (Mg^{2+}), leading to soil structural degradation and poor water infiltration. This compaction can cause water to move more slowly

through the soil, increasing the risk of waterlogging and adversely affecting plant health. Chemical analysis of soil and water samples is essential for identifying sodicity issues through metrics such as the Sodium Adsorption Ratio (SAR) and exchangeable sodium percentage (ESP). By implementing strategies like gypsum application and regular monitoring of soil chemistry, farmers can improve soil structure and enhance water infiltration, promoting sustainable irrigation practices.

Temperature, pH, and alkalinity of water sources and the concentration levels of major salt ions in water used for irrigation in the sub-catchments.

The temperature of irrigation water plays a crucial role in influencing both plant growth and soil chemistry. Higher temperatures can accelerate evaporation rates, concentrating salts in the remaining water, which may adversely affect crop health. Additionally, elevated temperatures enhance the solubility of certain nutrients and minerals, impacting their availability to plants. However, excessively high temperatures can stress plants, leading to reduced growth and lower yields. Therefore, maintaining optimal water temperatures is essential for ensuring healthy crop development and maximizing productivity.

pH and alkalinity are also critical factors in irrigation water quality, as they directly affect nutrient availability and soil health. Most crops, including rice, thrive within a slightly acidic to neutral pH range (approximately 6.0 to 7.5); deviations from this range can result in nutrient deficiencies or toxicities. High pH can limit the availability of essential micronutrients like iron, while low pH may increase the solubility of harmful elements such as aluminum. Alkalinity, which reflects water's capacity to neutralize acids, can also influence soil pH over time. High alkalinity can lead to increased soil pH, disrupting nutrient balance and hindering crop growth. Monitoring these parameters, along with the concentrations of major salt ions such as sodium, calcium, and magnesium, is vital for maintaining soil health and optimizing irrigation practices. By understanding these interrelated factors, farmers can implement effective management strategies to enhance agricultural productivity, especially SARO rice farming in the sub-catchments.

Conclusions

The research findings on the salt ions concentration levels in irrigation water in Tovuni Kiungoni, Zanzibar, highlight significant challenges posed by saltwater intrusion and sodicity. Elevated levels of sodium and chloride in irrigation water not only reduce the osmotic potential, making it difficult for crops to absorb water, but also lead to soil degradation through sodicity. These effects ultimately compromise crop yields and agricultural sustainability in the region.

Additionally, the study emphasizes the importance of monitoring critical water quality parameters, including temperature, pH, and alkalinity, which directly influence the health of the soil and the availability of nutrients to plants. Managing these factors is essential for optimizing irrigation practices and ensuring that crops thrive despite the pressures of salinity. Overall, addressing the implications of saltwater intrusion and implementing effective management strategies are crucial for enhancing agricultural productivity and resilience in TovuniKiungoni. By adopting targeted interventions, farmers can mitigate the adverse effects of salinity and foster a more sustainable agricultural environment.

Recommendations.

To manage the salt ion concentration levels in irrigation water in Tovuni Kiungoni, farmers should implement regular water quality testing to monitor sodium, chloride, calcium, and magnesium levels. Utilizing freshwater sources for irrigation where possible, especially during critical growth periods, can help mitigate the effects of saltwater intrusion. Additionally, incorporating practices such as leaching, where excess freshwater is applied to flush salts from the root zone, can effectively lower salinity levels.

Effect of Saltwater Intrusion and Sodicity on Infiltration.

To address the impact of saltwater intrusion and sodicity on soil infiltration, farmers should consider applying soil amendments like gypsum to help displace sodium ions and improve soil structure. Regular soil testing can provide insights into sodicity levels, allowing for timely interventions. Implementing sustainable irrigation practices, such as drip or sprinkler systems, can also enhance water application efficiency and reduce the concentration of salts in the soil.

Temperature, pH, and Alkalinity Management.

Farmers should monitor the temperature, pH, and alkalinity of their irrigation water regularly. Maintaining a slightly acidic to neutral pH (6.0 to 7.5) is ideal for nutrient availability. If the pH is found to be outside this range, appropriate amendments should be applied to correct it. Additionally, managing alkalinity levels through careful selection of water sources and treatment methods can prevent long-term soil health issues and improve crop yields.

Effects of Saltwater Intrusion on Saro Rice Farming

To mitigate the adverse effects of saltwater intrusion on Saro Rice Farming in Tovuni Kiungoni, farmers should prioritize the use of salt-tolerant rice varieties that are better suited to saline conditions. Training and capacity-building programs can help farmers understand the impacts of salinity and implement effective management practices. Collaborative efforts with local agricultural extension services can provide ongoing support and resources. Furthermore, developing community-based water management systems can ensure the sustainable use of freshwater resources and promote collective action against salinity issues.

Acknowledgments

I would like to express my heartfelt gratitude to all those who have supported me throughout the journey of completing this research dissertation.

First and foremost, I wish to thank my supervisor, Dr. Henry Stanley Mbowa whose guidance, expertise, and encouragement have been invaluable. Your insightful feedback and unwavering support have significantly shaped this work and inspired me to push beyond my limits.

I am also grateful to my research committee members of Kampala University for their constructive suggestions and insights, which enriched the quality of this dissertation. Your diverse perspectives have been instrumental in refining my research.

A special thanks to my colleagues and friends who provided moral support and camaraderie during the challenging moments of this process. Your encouragement kept me motivated and focused.

I would also like to acknowledge the institutions and individuals who contributed data and resources necessary for this research. Your willingness to share information was vital to the success of this project.

Finally, I would like to thank my family for their endless support and encouragement. Your belief in me and your patience throughout this journey have been my anchor.

This dissertation is a culmination of the collective efforts of many, and I am deeply grateful to everyone who played a role in its completion. Thank you.

List of abbreviations.

mg/L Milligrams per Liter
WHO World Health Organization
IPCC Intergovernmental Panel on Climate Change
°C Saltwater intrusion
SWI Degrees Celsius
CGIAR Consultative Group on International Agricultural Research
ASAL: Arid and semi-arid lands
FAO Food and Agriculture Organization
Na+ Sodium
Mg2+ Magnesium
K+ Potassium
Cl- Chloride
SO42- Sulfate
HCO3- Bicarbonate
CO32- Carbonate
NO3- Nitrate
Ba Barium
Sr Strontium
Li Lithium
Rb+ Rubidium
Fe Iron
Mo Molybdenum
Mn manganese
Al3+ Aluminum
URT United Republic of Tanzania
UNDP United Nations Development Programme
ANOVA Analysis of Variance
AFEID Association Française pour l'Étude de l'Irrigation et du Drainage
C Carbon
N Nitrogen
OH^- Hydroxyl Ion

H^+ Hydrogen Ion
GDP Gross Domestic Product
HCl : A Strong Acid Composed of Hydrogen and Chlorine
ml Milliliter
$CaCO_3$ Calcium Carbonate
NaCl Sodium Chloride (Table Salt)
$Mg(NO_3)_2$ Magnesium Nitrate
KCl Potassium Chloride
$AgNO_3$ Silver Nitrate
g Gra
NaOH Sodium Hydroxide
EDTA Ethylenediaminetetraacetic Acid
MEDTA Molar Solution of Ethylene-diamine-tetra-acetic Acid.

Source of funding.

There is no source of funding.

Conflict of interest.

No conflict of interest was declared.

Availability of data.

Data used in this study are available upon request from the corresponding author.

Authors contribution.

AMK designed the study, conducted data collection, cleaned and analyzed data, and drafted the manuscript, and HSM supervised all stages of the study from conceptualization of the topic to manuscript writing and submission.

Authors biography

Abdi Mzee Kitwana is a student of a master's degree in Science of Environment at the Graduate School and Research, Kampala University.
Henry Stanley Mbowa is a research supervisor at the Graduate School and Research, Kampala University.

References.

1. Food and Agriculture Organization (FAO). (2020). *Sustainable rice production in Africa*. Rome: FAO.
2. Food and Agriculture Organization (FAO). (2021). *Managing salt-affected soils for sustainable agriculture*. Rome: FAO.
3. Guimond, J. A., and Michael, H. A. (2021). Effects of marsh migration on flooding, saltwater intrusion, and crop yield in coastal agricultural land subject to storm surge inundation. Water Resour. Res. 57 (2), e2020WR028326.
4. Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Cambridge: Cambridge University Press.
5. IPCC (2019). "Summary for policymakers," in Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press).
6. IPCC (2023). Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
7. IPCC (2024). Climate change 2014: mitigation of climate change. Cambridge. United Kingdom and New York, NY, USA: Cambridge University Press.
8. Moshi, E., Lema, N., & Salum, A. (2021). *Agricultural transformation in Zanzibar: The role of improved rice varieties*. African Journal of Agricultural Research, 16(3), pp. 201-210.
9. Boonwichai, S., Shrestha, S., Pradhan, P., Babel, M. S., & Datta, A. (2021). Adaptation strategies for rainfed rice water management under climate change in Songkhram River Basin, Thailand. *Journal of Water and Climate Change*, *12*(6), 2181–2198. https://doi.org/10.2166/wcc.2021.220
10. Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts, and approaches for reducing the risks. *Heliyon*, *9*(8), e18507. https://doi.org/10.1016/j.heliyon.2023.e18507
11. Liu, S., Cui, S., Adamowski, J. F., Wu, N., Wu, M., Zhang, P., & Cao, X. (2024). Assessing the impact of various irrigation technologies on agricultural production: A water-energy-carbon nexus perspective. *Science of The Total Environment*, *954*, 176809. https://doi.org/10.1016/j.scitotenv.2024.176809
12. Modi, R. (2019). The Role of Agriculture for Food Security and Poverty Reduction in Sub-Saharan Africa. In T. M. Shaw, L. C. Mahrenbach, R. Modi, & X. Yi-Chong (Eds.), *The Palgrave Handbook of Contemporary International Political Economy* (pp. 391–410). Palgrave Macmillan UK. https://doi.org/10.1057/978-1-137-45443-0_25
13. Omar, M. M., Shitindi, M. J, Massawe, B. H. J, Fue, K. G, Meliyo, J. L, & and Pedersen, O. (2023). Salt-affected soils in Tanzanian agricultural lands: Type of soils and extent of the problem. *Sustainable Environment*, *9*(1), 2205731. https://doi.org/10.1080/27658511.2023.2205731
14. Su, Q., Kambale, R. D., Tzeng, J.-H., Amy, G. L.,

Ladner, D. A., & Karthikeyan, R. (2025). The growing trend of saltwater intrusion and its impact on coastal agriculture: Challenges and opportunities. *Science of The Total Environment*, *966*, 178701. https://doi.org/10.1016/j.scitotenv.2025.178701

15. Yadav, M., Vashisht, B. B., Jalota, S. K., Jyolsna, T., Singh, S. P., Kumar, A., Kumar, A., & Singh, G. (2024). Improving Water Efficiencies in Rural Agriculture for Sustainability of Water Resources: A Review. *Water Resources Management*, *38*(10), 3505–3526. https://doi.org/10.1007/s11269-024-03836-6

PUBLISHER DETAILS

SJC PUBLISHERS COMPANY LIMITED

SJC Publishers Company Limited
TODAY AND TOMORROW

Catergory: Non Government & Non profit Organisation
Contact: +256 775 434 261 (WhatsApp)
Email: info@sjpublisher.org or studentsjournal2020@gmail.com
Website: https://sjpublisher.org
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa