American Journal of Climate Change, 2024, 13, 664-681
https://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Assessing the Impact of Climate Change and Variability on Pesticides-Usage for Rice (*Oryza sativa* L.) Farming in Zanzibar

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How to cite this paper: Suleiman, A. N., Kai, K. H., & Amour, K. O. (2024). Assessing the Impact of Climate Change and Variability on Pesticides-Usage for Rice (*Oryza sativa* L.) Farming in Zanzibar. *American Journal of Climate Change, 13,* 664-681.
https://doi.org/10.4236/ajcc.2024.134030

Received: February 2, 2024
Accepted: November 29, 2024
Published: December 2, 2024

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Abstract

The study aimed to investigate the impact of climate change and variability on pesticide usage for rice production in Zanzibar. Anecdotal information from interviewer responses, climate datasets from the Tanzania Meteorological Authority (TMA), rice production records (in tones) and pesticide (in liters) were acquired from Ministry of Agriculture, Livestock and Natural Resources. Pearson correlation ($p \leq 0.05$) was used to determine the relationship between rice productions, and pesticide usage under different climate conditions. Paired t-test was used to understand mean significant difference of the used parameters for 2012-2017 and 2016-2020 periods. Time series graphs and charts were used in results presentation and discussion. Results revealed a strong correlation between pesticides and rainfall with climate parameters in rain-fed farms and weak ones in irrigated farms. For instance, strong correlation of r = 0.6 to 0.8 ($p \leq 0.05$) between rainfall and rice production was shown at Pondeani, and Kinyakuzi rice farms. Moreover, minimum temperature had strong correlation (r = 0.7, 0.6, and 0.5) with pesticides in rice farms of Pondeani, Mwera, Mtwango, and Kinyakuzi, respectively, while maximum temperature had weak correlations (r = ±0.4). Also, respondent's response has shown that pesticides have large spectrum of impacts on human health, soil fertility, biodiversity, and environmental issues. Besides, results have shown that rice farmers in Zanzibar had inadequate education and skills on pesticide usage, resulting in spending more on pesticides, hence leading to poor yields. Thus, the study concludes that climate has significant impact on rain-fed rice production schemes while pesticide usage has great impact on production environment and human health. Hence, extensive awareness on effective usage of pesticide for rice farmers in

Zanzibar is highly recommended.

Keywords

Rice Production, Climate Parameters, Rain-fed, Irrigation, Paired T-Test

1. Introduction

Climate changes have important implications for the conservation of pesticide situation. Climate and weather can substantially influence the development and distribution of both pesticides and crops. The Environmental Protection Agency (EPA) defines a pesticide as any substance or mixture of the substance used for preventing, destroying, repelling, or mitigating any pest (Kanaan et al., 2019). According to IPCC, among the greatest environmental challenges of the 21st century is global climate change, leading to increased atmospheric concentration of Greenhouse Gases (GHGs), increased global temperature, changing precipitation patterns, and increased frequency of extreme weather events, such that the agriculture and world supply of the food and fibers are particularly vulnerable to such climate change (Materu et al., 2021).

In Tanzania, Zanzibar, in particular, for long-time history, agriculture has continued to be the pillar that supports livelihood in high proportion. The agricultural sector is responsible for ensuring food security that can support over the 1.98 million people residing in Zanzibar. Climate change is believed to increase the number of insect pests, diseases, and weeds. So, the farmers are recommending strategic use of these pesticides to control insect pests, diseases, and weeds in rice farms. Though pesticides help in controlling insect pests, and diseases, pesticides are chemicals that have negative effects. For instance, they cause the destruction of soil micro-fauna and flora, also, their residual accumulation in soil and food crops may result in low quality and quantity of rice yield (Tetteh & Glover-Amengor, 2008).

Zanzibar has developed strategies to address climate change, including the national adaptation program, climate resilience plan (2014-2019) and climate-smarts agriculture (CSA) programmers (2015-2025). These efforts aim to enhance climate adaptive capacity, accelerate the adoption of climate-smart agriculture, and reduce GHG emissions. Also, climate smart aims to increase awareness among stakeholders, including extension officers and smallholder farmers, about adaptations and mitigation to build resilience in agricultural farming enterprises, improving productivity and food sustainability (Rioux et al., 2017).

Despite these undertaken efforts, there are some challenges to CSA in rice farming and pesticide usage. For instance, low skills in the usage of pesticides can cause problems like the killing of non-target organisms and polluting the soil (Irawan & Antriyandarti, 2021). Irrespective of these highlighted challenges, there exist either little or no documented studies and best practices that explain the impact of climate change on pesticide usage for rice farming in Zanzibar. Moreover, there exists an inadequate level of understanding of the exact usage of these pesticides for rice farming especially on irrigation farms. Thus, this study aims to investigate the impacts of climate change and variability on pesticides usage for rice farming in both irrigation and rain-fed schemes. Specifically, the study engaged on understanding 1) the common types of pesticides mostly used in rice farming in Zanzibar, 2) the relationship between climate change variables (temperature, rainfall, and wind) and pesticide usage for rice farming, and 3) examine the effects of pesticide usage on rice farming. The finding of this study may inspire the farmers to minimize the frequent usage of pesticide in their rice farming practices. Also, the study may provide proper information to policy makers, agricultural managers, and extension officers on the status and impacts of pesticide usage under climate change conditions and how to adapt to the existing situation.

2. Data and Methods

2.1. Study Area

Zanzibar is a semi-autonomous state in Tanzania, which consists of two islands, Unguja and Pemba, located in the Western India Ocean. Unguja spans 1666 km^2, while Pemba covers 988 km^2 and is 50 km north of it (Hassan, 2017). The climatic condition is tropical climate in the region, characterized by humidity and temperature fluctuations, which normally put pressure and impacts agricultural activities. Zanzibar has two rainfall patterns i.e. long rain (MAM) with heavier precipitation and short rain (OND) (Kai et al., 2020). Also the Zanzibar's climate is moderately influenced by southwestern Indian Ocean (SWIO) tropical cyclones, which may enhance or decline the seasonal rainfalls based on its position, truck, and orientation (Kai, 2018; Kai et al., 2022). Zanzibar experiences average maximum and minimum temperatures of 31.0˚C and 22.7˚C, respectively, and average total rainfall of 202.5 mm at Unguja and 169.29 mm at Pemba (Kai et al., 2021).

2.2. Study Sites

The study was conducted in six rice farms, of which three farms are found on each island of Unguja and Pemba. The rice farms in Unguja are Mtwango, Cheju, and Mwera, while that of Pemba are Weni, Pondeani, and Kinyakuzi, respectively (**Figure 1**), and out of these farms, four are irrigated and two are rain-fed.

The short description and geographical positioning of these farms include 1) **Mtwango**, is situated in west "B" district, with coordinates 6˚19'7"S and 39˚30'4"E. The types of farming are irrigation scheme and it covers an area of about 83.6 hectors. 2) **Cheju** is located at the center of North A district region in Unguja, with, its coordinates of 5˚97'5"S and 39˚30'9"E, this farm uses both irrigation and rain-fed schemes, and covers an area of about 95 hectors. 3) **Mwera** is located in the west "A" district with coordinates of 6˚15'3"S and, 39˚26'5"E. The farm uses an irrigation scheme with an area of about 15 hectors. 4) **Weni** is located in Wete (Pemba) and is considered as a peri-urban place with grid position of 5˚05'1"S, 39˚73'8"E and an area of about 40 hectors. **5) Pondeani** is located in

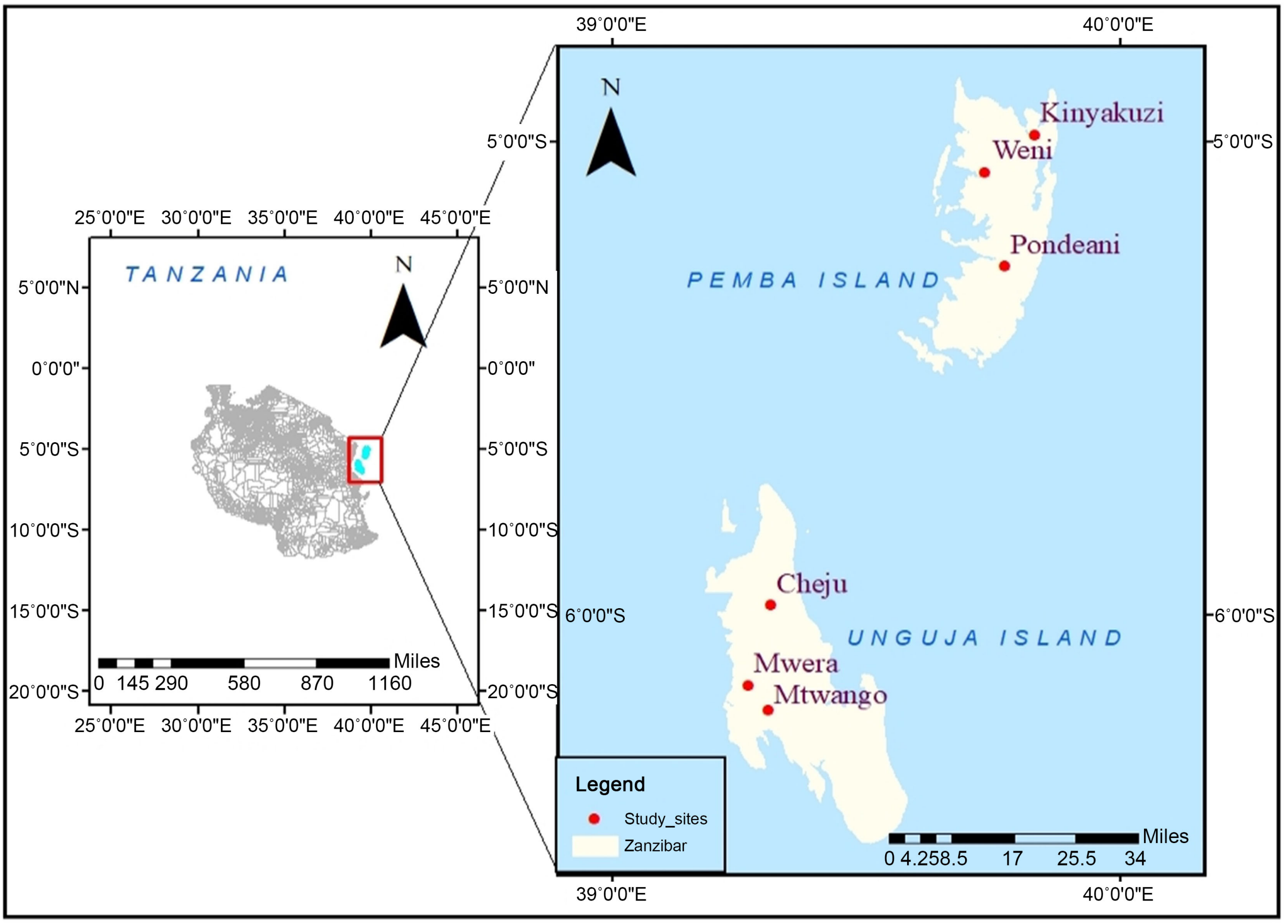

Figure 1. The maps show the study area, and the meteorological data sites (Source: The Tanzania administration GIS layer).

the Chake—Chake district in Pemba with coordinates of 5˚26'2"S and, 39˚76'5"E. The rice farms in Pondeani run both irrigation and the rain-fed, which employs large number of farmers depending on rain-fed. The farm covers an area of about 15 hectors. 6) **Kinyakuzi** is found in Micheweni district in Pemba with coordinates of 4˚97'8"S and 39˚82'1"E, and cover an area of about 18.75 hectors.

2.3. Data and Data Processing Using Excel Worksheet

The study used two different types of data: 1) The anecdotal information, which was gathered through questionnaires and interviews with extension officers and farmers at the aforementioned study sites 2) rice production(tones) and pesticide usage (litters) for period of 10 yrs 2012 to 2021). These data sets were obtained from the Ministry of Agriculture, Livestock, and Natural Resources and 3) the climate data (rainfall, maximum and minimum temperature and wind) which was acquired from Tanzania Meteorological Authority (TMA) at Zanzibar offices. The approaches utilized to establish the importance of the anecdotal responses included sorting anecdotal responses using excel sheets, calculating the Pearson/Spear-men correlation analysis, and performing paired T-tests.

3. Results

3.1. Common Types of Pesticides Mostly Used in Rice Farming in Zanzibar

The results of the pesticide usage among rice farmers, under criterion of common types, frequency, storage, season use, and their impact on rice harvesting and storage, showed that farmers in Zanzibar uses variety of pesticides, with insecticides being the most commonly used (Figure 2(a)) at 49.2%, followed by weeds at 29.2% and fungicides at 21.6%.This indicates that rice farmers use various pesticides to control weeds and insects, leading to significant increases in agricultural products as noted by Palikhe (2007) that about one-third of agricultural production relies on pesticides, preventing significant losses in fruit, vegetable, and cereal production.

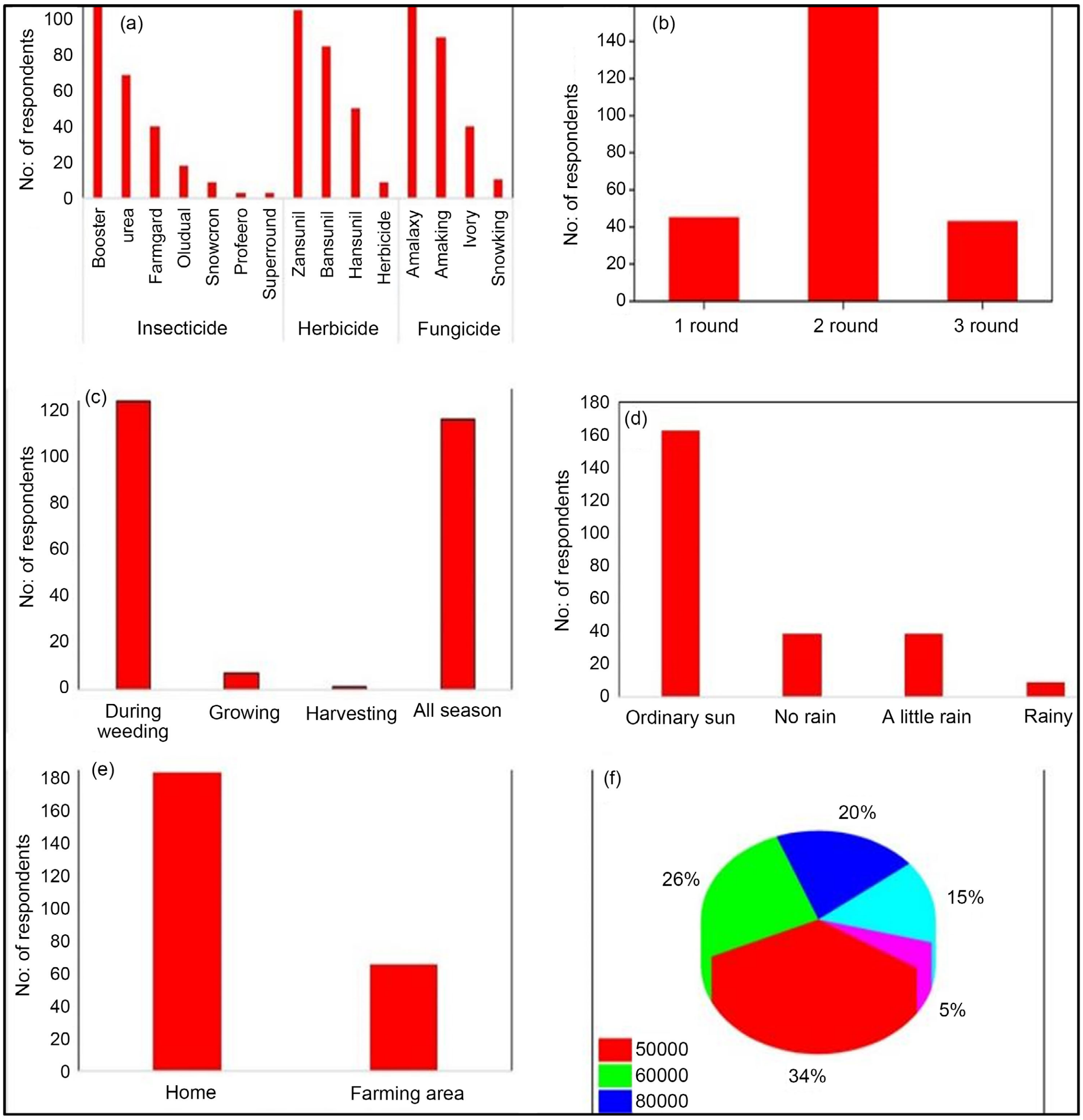

Figure 2. Common types of pesticides mostly used for rice farming in Zanzibar.

Furthermore, the study result indicates that various pesticides, including insecticides, weeds, and fungicides, which significantly reduce diseases and improve crop yields are used by the rice farmers. For instance, insecticides (including booster, farm guard, snow-cron, and duduall), weeds (including zansunil, bansunil, hansunil, and 2,4D turbo herbicide) and fungicides (ivory, snowking, and amalaxy) are widely used for rice farming in Zanzibar. As for the frequency of spraying the pesticides, **Figure 2(b)** shows that 79.6% of rice farmers use two rounds of pesticides spraying, whereas 12.8% use one, and 7.6% use three rounds. As for the instances or stages of using pesticides, results in **Figure 2(c)** indicates that Zanzibar rice farmers use pesticides 1 - 3 stages per growing season to improve crop yields and ensure food security, as agreed by the majority of respondents (50%) use pesticides during weeding, while 46.8% responded on both growing and harvesting periods. This results aligns with Abouziena & Haggag (2016) and Belsky & Joshi (2020) who noted that weed control with pesticides is labor-intensive, especially in areas with high temperatures and regular rainfall like Zanzibar. As for the weather conditions of using pesticides results in **Figure 2(d)** revealed that 65.2% of the respondents are spraying the pesticides during sunny intervals, (15.6%) responded on no rain, while 3.6% were in favors of sunny and rainy periods.

The study results of spraying pesticides during sunny periods are in agreement with Nkua (2017) who noted that spraying for insecticides and herbicides, in normally performed during dry periods. As for the pesticide storage, results in **Figure 2(e)** revealed that majority of respondents (73.6%) stored pesticides at home, while 24.4% stored them in their farming areas. This safe storage of pesticides has been highly emphasized by Sekabira and Tam (2022) who noted that proper pesticide storage protects people, animals, and the environment, extends shelf life, and prevents cross-contamination, reducing environmental risks like groundwater contamination, wildlife death, plant damage, and soil contamination.

As per the expenditure on pesticide per season of rice farming results in **Figure 2** indicates that 34% of respondents use less than 21.3 US$ per season while 66 (26%) used 25.5 US$ per season, 50 (20%) used 34.1 US$, 38 (15%) used 38.3 US$ per season and only 11 (5%) used more than 42.6 US$ per season. These responses show that the budget used but Zanzibar rice farmers is very small resulting in poor yields due to pest infections, diseases, and insects. In comparison to other countries this budget seems to be inadequate. For instance, in 2013, farmers in Nepal and Sri Lanka spent between US$61 and US$32 per year on pesticides, while in Mali; they needed between US$30 and US$60 per year. Rice farms account for 15% of pesticide use and 27% expenditure as noted by Aktar et al. (2009).

3.2. Relationship between Climate Parameters (Temperature, Rainfall, and Wind) and Pesticide Usage

The results of the relationship (correlation) between climate parameters, rice production and pesticides, presented in Table 1 shows that rainfall has become a crucial factor in rice production in Pemba Island, due to the highest correlation with rice yields in rain-fed farms. For instance, rice farms of Pondeani and Kinyakuzi had shown significant correlations of 0.8 and 0.6 (at $p \le 0.05$) while farms in Unguja had weak correlation. The low correlation at Unguja farms could be due to existing irrigation schemes, resulting in less rainfall requirement, suggesting rainfall might not be a crucial factor as agreed by Palikhe (2007). Further results revealed that rain-fed farms in Pemba had strong significant negative correlation with minimum temperature. Furthermore, the study found a weak positive correlation between maximum temperature and rice production on rain-fed farms in both Pemba and Unguja, suggesting that maximum temperature can impact rice production growth, particularly during the vegetative phase, as it increases photosynthesis rate and shortens the crop life cycle, resulting in decreased production.

Table 1. Correlation between rice production and climate parameters, note that bolded numbers are significant at $p \le 0.05$.

	Rainfall (rain-fed)	Min temp	Max temp	Wind (09 am)	Wind (03 pm)
Cheju	0.22	−0.22	−0.12	**−0.51**	−0.36
Mwera	0.34	−0.26	−0.26	0.012	0.014
Pondeani	**0.81**	**−0.57**	0.33	−0.38	−0.01
Kinyakuzi	**0.6**	**−0.64**	0.21	−0.34	−0.06

As for the relationship between winds at 09 am and 03 pm, results in Table 1 indicated no significant positive correlation between wind and rice production in rain-fed farms, but a negative correlation was found in Unguja farms. Strong winds at 3.00 pm. may decline rice production during growing and productive stages, as they may displace pollination and result in poor yields, while light wind speeds can lead to thicker and stronger stems, However, a high correlation was found at 3:00 pm (15 hrs local time) in Unguja farms, with weak correlations at Pondeani, Kinyakuzi, and Mwera. In Table 1, it should be noted numbers in bold are significant at $p \le 0.05$)

3.2.1. The Correlation between Rice Production and Climate Variables in Irrigated Rice Farms

The results in Table 2 reveal weak correlations between rice production and climate parameters on irrigation scheme farms during MAM, except in farms of Mtwango and Cheju which had high correlations. Maximum temperature correlations were strong negative, in Mwera (i.e. r = −0.52). Also Table 2 shows that minimum temperature significantly impacts rice production in Pemba, while Unguja's farms have weaker effects. As for wind strength at 09.00 am and 3.00 pm also affects rice production, with Mwera rice farm showing a higher positive correlation (r = 0.51) leaving Pemba farms with weaker correlations. Based on these results, the study suggests that irrigated farms benefit from wind at 09.00 am to reduce excessive water as agreed by Materu et al. (2021).

Table 2. Correlations between rice production and climate variables on irrigated rice farms during the MAM season at ($p \leq 0.05$).

	Rainfall	Max temp	Min temp	Wind (09 am)	Wind (03 pm)
Cheju	0.42	−0.52	**−0.64**	0.43	0.19
Mtwango	**0.62**	−0.19	−0.02	−0.03	−0.05
Mwera	0.38	0.12	−0.08	0.32	0.51
Weni	0.19	−0.31	**−0.58**	0.13	0.3
Pondeani	0.18	−0.36	−0.51	−0.49	**−0.61**
Kinyakuzi	0.24	−0.08	−0.19	0.15	0.33

Results in Table 3 show a weak positive correlation between rainfall and rice production in Unguja farms and a negative correlation for Pemba farms. The study also found that high temperatures and strong winds partially reduced rice yield in Zanzibar's rice farms. The correlation between maximum temperature and production was negative for farms in Unguja, Pemba, and moderate correlations were found in Cheju and Weni for minimum temperatures and winds. Moreover, results revealed that decrease in rainfall pattern has affected almost all rain-fed rice farms in Zanzibar; suggesting that high temperatures and strong winds are key factors affecting rice production. Indeed, the study found a moderate to strong negative correlation between temperature and rice production, with a strong negative correlation as noted by Martínez-Megías et al., 2023 and Mussa & Massomo, (2019), as well as Singh & Awais (2019). Those high temperatures affect rice yields and grain quality, Furthermore, Table 3 shows weak negative and positive correlation between wind and rice production, indicating that low wind speeds can lead to thicker stems, while increased wind speeds can cause thinner ones.

Table 3. Correlations between rice production and climate variables on irrigated rice farms during OND season at ($p \leq 0.05$). Note that number in bold is significant at ($p \leq 0.05$).

	Rainfall	Max temp	Min temp	Wind (09 am)	Wind (03 pm)
Cheju	0.06	−0.47	0.37	**0.58**	0.49
Mtwango	0.08	−0.36	−0.05	−0.16	−0.005
Mwera	0.06	−0.23	−0.11	0.06	0.07
Weni	−0.20	**0.77**	0.13	**0.64**	0.28
Pondeani	−0.17	−0.37	−0.36	−0.18	−0.15
Kinyakuzi	−0.13	−0.14	−0.21	−0.24	−0.13

3.2.2. Correlation between Pesticide Usage and Climate Variables

The results of the relationship between temperature, rainfall, and wind with pesticide usage presented in Table 4 to Table 5 show that the highest correlation between rainfall and pesticide usage was found in Pemba rice farms of Pondeani, Kinyakuzi, and weak correlations in Weni, Mwera, Cheju, and Mtwango. These results indicate that rainfall affects rice production, and pesticides can enhance yield and quality if used sparingly and not frequently, as agreed by Singh et al. (2013). As for correlation between Tmax and pesticides results were strong and significant at Kinyakuzi (r = 0.6; $p \le 0.05$), Mwera and Cheju (r = 0.5; $p \le 0.05$), and Pondeani (r = 0.4; $p \le 0.05$), while the rice farms of Mtwango and Weni had a weak correlation indicating that rice farms having both rice farming schemes (i.e. rain-fed and irrigation) the maximum (T_{max}) does not affect the performance of pesticides as agreed by Irawan and Antriyandarti (2021). The results also showed that the (T_{min}) had a strong correlation in Pondeani Mwera, Mtwango, and Kinyakuzi with coefficients of 0.7, 0.6 0.5, respectively.

Table 4. Correlation between pesticides and climate variables for irrigation and rain-fed schemes in Unguja at ($p \le 0.05$). Numbers in bold are significant at $p \le 0.05$.

Location	Rainfall	Temp Max	Temp Min	Wind 1	Wind 2
Mwera	**0.6**	0.5	**0.6**	0.2	0.1
Cheju	0.5	0.5	0.4	0.5	0.1
Mtwango	0.1	0.02	0.5	0.4	0.3

Table 5. Correlation between pesticides and climate variables for irrigation and rain-fed schemes in Pemba at ($p \le 0.05$). Numbers in bold are significant at $p \le 0.05$.

Location	Rainfall	Temp Max	Temp Min	Wind 1	Wind 2
Weni	0.5	0.05	0.2	0.5	0.3
Kinyakuzi	**0.6**	**0.6**	0.5	0.4	0.3
Pondeani	**0.6**	0.4	**0.7**	0.4	0.2

Also this high correlation between (T_{min}) and pesticides in some farms could be explained by the fact that in low temperature conditions pesticide sprays may not highly dispersed as well by Nguyen (2016) who noted that minimum temperatures are suitable for rice crops to grow under less frequent usage of pesticides. Also correlation results revealed weak correlation between wind flows at 09:00 am and 0300 pm with pesticide usage.

3.2.3. Paired T-Test Results

The results of the paired t-test for climate and production (rice yields, and pesticides) under the null hypothesis that "there is no significant difference in the mean of the used variables for the two periods of 2019-2022" in most irrigation farms the null hypothesis was rejected and the alternative hypothesis that "there is significant difference between the mean of the used variables for the two stated periods" (**Table 6**), reveal significant changes in climate parameters in Pemba (Kinyakuzi and Pondeani) than Unguja, with alternative hypotheses rejecting the null hypothesis on rice production and wind on rain-fed farms, with rainfall and temperature values being 0.04 and 0.03. Moreover, results in **Table 7** indicate that the red marked values accepted the null hypothesis and other values rejected the null hypothesis indicating exiting of significant deference between both climate and yield values for the two stated periods.

Table 6. Values of the probabilities for the paired t-test between production and climate variables for rain-fed in Unguja and Pemba (at $p \leq 0.05$).

Location	Production	Rainfall	Max temp	Min temp	Wind 1	Wind 2
Mwera	0.1	0.2	0.4	0.2	0.08	0.4
Cheju	0.06	0.06	0.4	0.3	0.06	0.5
Kinyakuzi	0.2	**0.04**	**0.05**	**0.04**	0.2	0.1
Pondeani	0.2	**0.05**	**0.03**	**0.04**	0.1	0.3

Table 7. Values for the probability (p) to the paired t-test between production and climate variables for the irrigation schemes in Unguja and Pemba (at $p \leq 0.05$).

Location	Production	Rainfall	Max temp	Min temp	Wind 1	Wind 2
Mwera	0.3	0.04	0.4	0.04	0.1	0.3
Cheju	0.4	**0.05**	0.4	**0.05**	0.2	0.2
Mtwango	0.1	**0.04**	**0.05**	**0.04**	0.1	0.2
Weni	0.4	**0.04**	**0.03**	**0.04**	0.1	0.4
Pondeani	0.1	0.03	0.03	**0.05**	**0.02**	0.3
Kinyakuzi	0.5	**0.05**	**0.03**	**0.04**	0.1	0.3

Unlike in the rain-fed farms, the results for the paired t-test for the irrigation schemes (Table 6) revealed that most parameters including rainfall, maximum and minimum temperatures had significant p values of less than 0.05, thus accepting the null hypothesis. This indicates that climate parameters except winds had little influence on rice production in Unguja and Pemba irrigation farms, indicating that wind plays a crucial role in pollination and evaporation processes.

The results in Table 8 and Table 9 are the values of the probability (p) to the paired t-test between production and climate variables for the irrigation schemes in Unguja and Pemba (at $p \leq 0.05$). Where in Table 8 only minimum temp and wind 1 at Cheju (Unguja) accepted the null hypothesis, and for max temp Pondeani and Kinyakuzi accepted the null hypothesis. In Table 9, the significant values ($p \leq 0.05$) accepted the null hypothesis indicating no significant difference of the related values for the two given periods.

Table 8. Values of the probability (p) to the paired t-test between production and climate variables for the irrigation schemes in Unguja and Pemba (at $p \leq 0.05$).

Location	Production	Rainfall	Max temp	Min temp	Wind 1	Wind 2
Mwera	0.06	0.3	0.05	0.04	0.03	0.04
Cheju	0.03	0.3	0.4	**0.05**	**0.05**	0.04
Mtwango	0.5	0.3	0.2	0.04	0.02	0.04
Weni	0.02	0.5	0.08	0.4	0.02	0.03
Pondeani	0.2	0.4	**0.05**	0.02	0.02	0.02
Kinyakuzi	0.4	0.2	**0.05**	0.03	0.1	0.3

Table 9. Values of the probability (p) to the paired t-test between production, pesticide usage and climate variables for the irrigation schemes in Unguja and Pemba (at $p \leq 0.05$).

Location	Production	Pesticide usage	Rainfall	Max temp	Min temp	Wind 1	Wind 2
Mwera	0.05	0.04	0.2	0.02	0.2	**0.05**	0.08
Cheju	0.04	0.03	0.2	0.08	0.4	0.06	0.4
Mtwango	0.4	0.3	0.1	0.2	0.4	0.1	0.9
Weni	0.02	0.02	0.3	0.2	0.02	0.2	0.4
Pondeani	0.04	**0.05**	0.04	0.1	0.01	0.1	0.3
Kinyakuzi	**0.05**	0.04	**0.05**	0.4	0.08	0.2	0.7

3.3. Effects of Pesticides Usage in Rice Farming

Among numerous advantages of utilizing pesticides is its ability to control harmful pests, illnesses, and exotic plants that can affect rice crops and the environment. However, using pesticides may also have negative impacts on the ecology, especially if sprayed in excess. Based on this study, the results revealed that majority of respondents (39.22%) mentioned that constant use of pesticides in rice farming activities has resulted in a loss of quality and quantity of rice yields. Only 2.8% of respondents mentioned health risks to the users, while 29.6% accepted pollution, 16.8% mentioned a loss in fertility, and 11.6% responded on the loss of biodiversity. These responses are in agreement with studies including: Parsons et al. (2010), Rath et al. (2018), Lange (2006), Matowo et al. (2020), Delcour et al. (2014) and Al-Ani et al. (2019) who noted that different pesticides have varying effects on adsorption, transport, disintegration, and degradation, resulting in crop removal, drift, runoff, leaching, and volatilization. Excess or frequent pesticide usage in rice farms can lead to rice quality and quantity loss, biodiversity loss, fertility loss, pollution, and health risks.

Farmers face challenges in coping with pests and diseases, necessitating timely pesticide training. Additionally, loss of fertility and biodiversity are significant issues, as noted by Ndayambaje et al. (2019). Also the study found that the frequent use of pesticides has led to a loss of fertility and biodiversity. Respondents (5%) These respondents responses are in agreement agreed with the studies of Abdullah et al. (1997), Nkua (2017) and Parsons et al. (2010), whom identified human health risks from constant pesticide use in rice fields, aligning with studies indicating the importance of pesticide use in agriculture. Also our study is well agreed by Irawan and Antriyandarti (2021) whom noted that rice farming innovations have increased the use of pesticides, causing negative impacts on rice quality, biodiversity, and water resource pollution. These chemicals pose potential risks to humans and other life forms, as they can also contaminate air, soil, and non-target plants.

Measures to Reduce Excessive Use of Pesticides in Rice Farming

The study examined the measures that should be taken to prevent frequent and constant use of pesticides in rice farming in Zanzibar. The respondents' responses indicate that majority of 73 (29.2%) noted that education and training could be the appropriate measures, 67 (26.8%) supported the use of organic fertilizers, while 61 (24.4%) mentioned the use of irrigation system as a measure to prevent excessive use of pesticides, and 29 (11.6%) said frequent visit and inspection of extension officers, and 20 (8%) favored for the recruitment of more extension officers. The study reveals positive changes in rice farming due to education, training, and increased inspections by extension officers, addressing the constant use of pesticides and organic fertilizers Figure 3 and the measures to prevent excess or frequent usage of pesticides in rice farming (Figure 4).

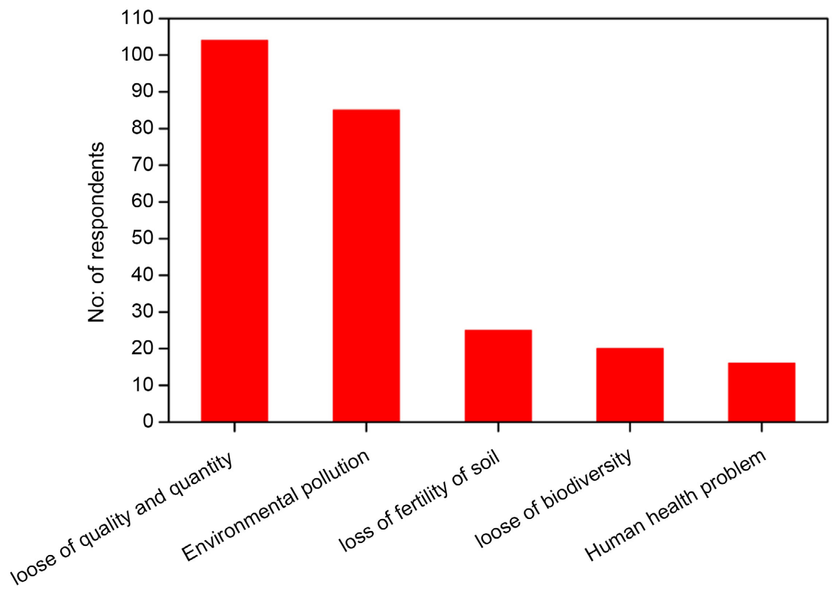

Figure 3. Proportion of effects of constant use of pesticides in rice farming as per respondent's perspectives.

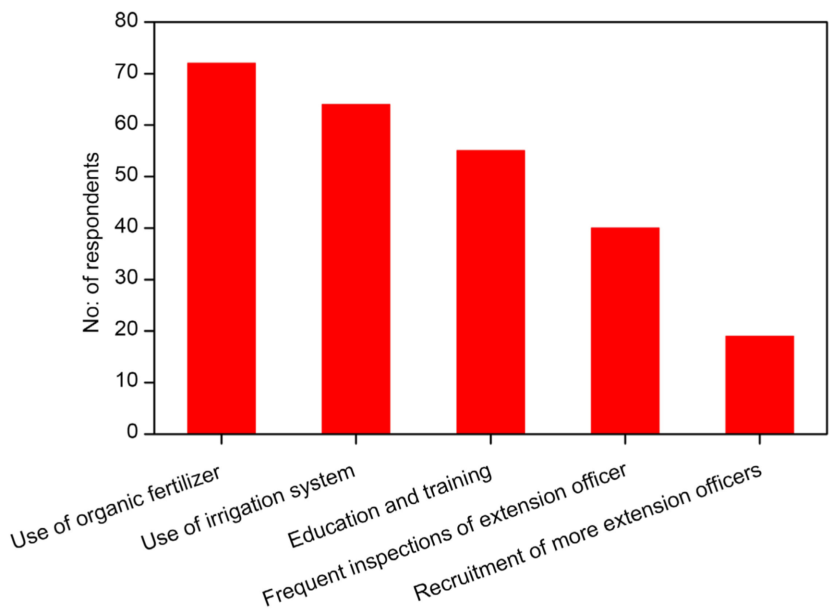

Figure 4. The proportion of the responses for the measures to prevent excess or frequent usage of pesticides in rice farming.

Indeed, our findings are agreed by Singh and Awais (2019), who noted that knowledge and skills acquired by rice farmers are useful in enhancing the quality of agricultural products to farmers under a changing climate. Also, the study is in agreement with Singh & Awais (2019), Mbilinyi & Kazi (2013), Nkua (2017) and Palikhe (2007) who pointed out the importance of education and training as it relates to climate change adaptation. As for the use of organic fertilizers, these results were well agreed by Maneepitak and Cochard (2014) who noted that the use of natural fertilizers leads to an augmentation of micro-biologic activity in the soil, while Organic fertilizers are broken down by organisms in humic acid and amino acids. Also, Singh et al. (2013) noted that the decomposition of natural fertilizers makes the soil structure lighter resulting in rich, healthy soil with good biodiversity created and a good environment for rice to grow.

The use of an irrigation system is among the measures mentioned by respondents as a substitute for the frequent and constant use of pesticides in rice farming in Zanzibar, which was well agreed by Materu et al. (2021) who noted that poor irrigation system management is exacerbated by the changes in precipitation patterns otherwise, the system should ensuring easy access of water, especially during dry or sunny season.

On the other hand, the frequent inspection of extension officers to rice farms is very crucial in discouraging the farmers from the frequent and constant use of pesticides in their rice farms. This is well agreed on several authors that the importance of extension service as it relates to climate change adaptation (Hassan, 2017; Martínez-Megías et al., 2023; Reid, 2012; Steffens et al., 2015; Singh et al., 2013).

4. Discussion

The study has assessed the impact of climate change and variability of pesticide usage for rice (*Oryza sativa*) farming in Zanzibar at the six rice farms of Mtwango, Mwera and Cheju in Unguja and Kinyakuzi, Pondeani and Weni in Pemba. The presented results revealed that different types of pesticides are used on the rice farms of Unguja and Pemba but commonly used ones by their groups include insecticide (booster, farmguard, snowcron, urea and duduall), weeds (Zansuil, Hansuil, bansuil and 2,4D turbo herbicide) and fungicide (Ivory, Snowiking, amalaxy and fungicide). The climate variables have significance correlation with rice production in some areas while other the correlation is weak and can vary from rain-fed to irrigation. For instance, rainfall had a higher correlation with production on the rain-fed farms of Cheju, Mwera, Kinyakuzi and Pondeani while weak correlation with irrigation farms of Weni and Mtwango, respectively.

Also the presented study results have shown that rice yields and application of pesticide are both greatly affected by temperature, indicating that higher production was contributed by a suitable increase in the mean maximum and minimum temperature. The higher temperature may affect the rice production through affecting the ground water supplied and decline in recharge that can lead the emergence of new insect pest or weed. This was showed at Kinyakuzi (in Micheweni) and Pondeani (in ChakeChake) in Pemba. Rainfall variation substantial impact on the rice productivity that can cause decrease in growth and production. Finding have shown that there is the higher significant correlation between rainfalls in production and the pesticide usage in rain-fed farms in Pemba than in Unguja weak correlation in less than 0.3 for irrigation farms in Pemba and correlation of 0.6 and 0.4 for irrigation in Unguja. The correlation analysis with pesticide usage and wind flow at 09:00 am and 03:00 pm all are weak, and can be contributed by the fact that only two TMA stations provides wind data and these station are farm from the investigated rice farms.

Based on the effect of pesticide used in the rice farming presented results revealed that current usage of the pesticide has both positives and negative effects. As the positive effect of the pesticide controlling dangerous pest disease and exotic plant, and the negative effect which includes drift, runoff, leaching and volatilization) so in constant use can result loss of fertility of the land use, biodiversity, loss of quality and quantity and in human health. This study finding is in agreement with Sharma et al. (2019) who noted that 2 million tons of pesticides are utilized annually worldwide. Also, our results of lower frequency of pesticide use are in agreement with Zhang et al. (2022) who noted that though pesticides are beneficial for crop production, extensive use of pesticides can possess serious consequences because of their bio-magnification and persistent nature. Also, Zhang et al. (2022) noted that rice farming pesticides became a vital tool for plant protection and for enhancing crop yield. Thus, the study could recommend effective pest management by using a wide range of pesticides to confront pests and increase crop production.

5. Conclusion

Regarding the undergone analysis, results, and discussion, the study concludes the following:

1) The use of synthetic pesticides has commonly increased in rice farming due to pest control, fungal disease eradication, and weed control, which reduces rice production losses and improves farmers' yields, but still, this is not well-known among rice farmers.

2) More than 12 types of pesticides are commonly used in rice farming in Zanzibar; these types include insecticide (Booster, Farmguard, urea, Alfatox and Duduall), Herbicide (Bansunil, Hansunil, and Zansunil) and Fungicide (snowking, Amalaxy). But due to existing climate change and variability some years, farmers are forced to use herbicide even in the irrigation schemes resulting in a loss in biodiversity, soil, formation, human health as well as the environment.

3) Increasing temperatures, changing precipitation patterns, and altered wind dynamics, have the significant impacts on the changing behavior of pesticides in the environment. For instance, the studies have revealed variable correlation between pesticide usage and maximum and minimum temperatures over the in-

vestigated rice farms.

4) The farmer's awareness on the existing scientific methodology and technology such as integrated pest management (IPM), as well as education and training for rice farmers, and increasing capacity building to extension officers (visiting the fields regularly for monitoring and investigation) and management of irrigation infrastructures may have the positive impact to the rice Farming in Zanzibar.

6. Recommendations

As for the undergone analysis, results, discussion, and conclusions, the study recommend the following measures to be taken by the responsible ministry and the government at larger for the fate of rice production in Zanzibar are:

1) The responsible ministries and departments should improve maintenance and management of irrigation systems in all districts to ensure that water flow is unimpeded and easy access to water, especially during dry or sunny seasons. The local authority should ensure that irrigation systems are consistently and properly maintained and/or improved.

2) The local authority should ensure that resources and capacity building for extension officers are improved to help farmers deal with uncertain climatic changes. This will enhance the quality of extension services provided to farmers under climate change conditions. Also, the farming areas should be kept very clean condition and should not be a place to keep garbage from the households.

3) The responsible authorities should encourage the use of organic fertilizers or bio pesticides to improve the soil's health and condition, which increases the fertility in rice farming. Organic fertilizers are ecological, environmentally friendly, and non-toxic, making them the best fertilizers for plants and crops in greenhouse farming.

4) The local authority should ensure that education and training on the proper and safe use of pesticides to the rice farmers are provided effectively to avoid frequent and constant use of synthetic pesticides. The need to improve farmers' knowledge and practical skills in optimizing the use of pesticides on rice farms is very critical.

5) The government should ensure that matters concerning climate change and its variability are well communicated and disseminated in the villages including being discussed at a village meeting.

6) The local authority should conduct training for local community/farmers and extension officers to build more capacity regarding climate change and the utility of climate information.

7) The effective policy guidelines, pesticide regulation, and its effective implementation, motivation of farmers and extension staff, effective environmental technology transfer, promotion of participatory oriented extension programs, awareness building through mass media, expansion of IPM practices, situation analysis, and integration of local knowledge need to be fully improved.

8) The government should improve the system of climate change information and provision in all districts. This will help to facilitate quick access of information to farmers, monitor climate information and how it is accessed and used by farmers, and provide timely more accurate and specific areas of climate information.

9) The government should ensure that Integrated Pest Management (IMP) and Improved Management Practices are immediately adopted. Therefore, the local authority should emphasize the importance of IPM and encourage its adoption through various farmers' education programs and activities.

Acknowledgements

We would like to extend our special thanks to the Ministry of Education Vocational Training (WEMA), Tanzania Meteorological Authority (TMA) Zanzibar offices, and the Ministry of Agriculture Livestock and Natural Resources of Zanzibar for their great contributions in facilitating this work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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