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# The Influence of Climate Variability on the Watermelon Production in Zanzibar

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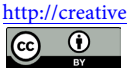




## Abstract

Climate change and variability, has embarked societies in Zanzibar to rely on horticulture (*i.e.* watermelon production) as an adaptive measure due to an unpromising situation of commonly used agricultural yields. Currently, there is either no or scant information that describes the influence of climate changes and variability to watermelon production in Zanzibar. Thus, this study aimed to determine the influence of climate variability on the quantity of watermelon production in Zanzibar. The study used both primary and secondary datasets, which include the anecdotal information collected from interviewers' responses from four districts of Unguja and Pemba, and climate parameters (rainfall, maximum and minimum temperature (Tmax and Tmin) acquired from Tanzania Meteorological Authority (TMA) at Zanzibar offices. Pearson correlation was used for analyzing the association between watermelon production and climate parameters, while paired t-test was applied to show the significance of the mean differences of watermelon and climate parameters for two periods of 2014-2017 and 2018-2021, respectively. Percentage changes were used to feature the extent to which the two investigated parameters affect each other. The anecdotal responses were sorted, calculated in monthly and seasonal averages, plotted and then analyzed. Results have shown a strong correlation ($r = 0.8$ at $p \leq 0.02$, and $r = 0.7$) between watermelon production, Tmax and rainfall during OND, especially in Unguja, as well as Tmin during JJA (*i.e.* $r = -0.8$ at $p \leq 0.02$) in Pemba. Besides, results have shown the existence of significant differences between the means of watermelon production and climate parameter for the two stated periods, indicating that the climate parameters highly affects the watermelon production by either enhancing or declining the yields by 69% - 162% and 17% - 77%,

respectively. Moreover, results have shown that respondents were aware that excess temperature intensity during dry periods can lead to high production costs due number of soil and other environmental factors. Besides the results have shown that OND seasonal rainfall and MAM Tmax had good association with watermelon production in Unguja while JJA Tmin declined the production in Pemba. Thus, the study concludes that seasonal variability of climate parameter has a significant influence on the watermelon production. The study calls for more studies on factors affecting watermelon production (e.g. soil characteristics, pest sides and manure), and recommends for climate based decision making on rain fed agricultural yields and routine monitoring of weather information.

## Keywords

Watermelon, March to May (MAM) and October to November (OND) Seasonal Rainfall, Maximum and Minimum Temperature, Anecdotal Information

## 1. Introduction

Traditionally, Zanzibar was relying on agriculture as the backbone of its economy, and currently the sector contributes to about 22.8% of its GDP [1]. Based on the degradation of the agricultural yields due to various reasons including climate change and variability [2] the community has embarked to "horticulture" as a substitute product or adaptive measure to meet the people's growing needs in food and safety as well as in health benefits. Horticulture is more pronounced on growing fruits, vegetables, flowers, or ornamental plants including cabbage, tomatoes, watermelon amongst others. Watermelon has emerged to the forefront in research advances due to its number of benefits including high nutrient values and anti-aged fruit caused by the presence of lycopene. Many studies including [3] have shown that watermelon moisturizes the skin, refreshes the body and may serve as a powerful laxative for intestines. Indeed, watermelon helps in digestion, strengthens the blood, and breaks the kidney stones. Also reference [3] noted that watermelon helps to reduce the severity of skin diseases, and its seeds help to reduce the high blood pressure, as well as stopping bleeding. Their seeds are considered to be highly nutritious, as they are rich sources of proteins, amino acids, omega 3 and 6 fatty acids, magnesium, zinc, copper, potassium and vitamins. Vitamin K in watermelon helps to treat and prevent unusual bleeding by increasing the body's production of blood clotting factors.

In Zanzibar, the growing of watermelon for domestic purposes was practiced a long time ago, but due to its socio-economic benefits, currently has become a commercial product that in a short time can change the socioeconomic status of the society and hence increase the country's GDP. Irrespective of its mushrooming in large quantity in Zanzibar, but its contribution to GDP is either

not well documented or not known. Also the scientific community has not largely engaged in doing research works on factors affecting the production of watermelon. For instance, nor study was conducted to understand the spatial distribution of watermelon production, *i.e.* which conducive environments affect the watermelon growth, and how the climate change and variability may affect the production of watermelon in Zanzibar. Based on its importance in adding value for money and health (nutrients), this study aimed to determine the influence of climate variability on the production of quantity of watermelon in Zanzibar, and specifically the study assessed 1) the influence of maximum and minimum temperature on the quantity of watermelon production; 2) the influence of seasonal rainfall on quantity of watermelon production; and 3) examining the degree to which rainfall and temperatures variability affects the quantity of watermelon production. The findings of this study may encourage the farmers to highly benefit from this product, and hence practices this farming on the favorable time, including minimizing the risk of insufficient or poor yields to farmers and thus increasing their socioeconomic and livelihood status. Indeed, the study is very crucial to policy makers, agricultural and nutritionists' managers, as well as to local and international investors for developing sustainable strategies and environments for production of watermelon in Zanzibar and Tanzania at large.

## 2. Data and Methods

### 2.1. Study Area

The study was conducted in Zanzibar (Unguja and Pemba), where four districts which produces watermelon for were purposively selected for investigation. These districts include Kaskazini B and Kusini for Unguja and Chake Chake and Micheweni for Pemba (**Figure 1**). Geographically, Zanzibar is characterized by low land Islands surrounded by Indian Ocean, with its land covered by vegetation and dense coconut trees. The coastal structure is dominated by coral reefs, mangroves, and sea grass meadows habitats. Almost 10 types of soil which includes fertile sandy loams and deep red (normally occurs on high ground), and gray and yellow sandy (found on valley bottoms and are less fertile) are recognized in Zanzibar.

Climatically, Zanzibar has balmy weather and warm tropical hot round the year, and is renowned for clear warm waters which is a home of idyllic beaches. This archipelago lies on a bimodal regime that has two distinct rainy seasons [4] [5] of MAM (long rains) which is wet, humid and mostly cloudy and OND (short rains). Dry season is warm, windy and mostly clear. The mean annual rainfall is about 900 mm and an annual evaporation potential of about 1600 mm. The temperature is rarely to below 18˚C and above 35˚C [5]. The socioeconomic livelihoods of Zanzibar community include agriculture, aquaculture, seaweed farming, livestock and artisanal fishing activities with fishing and farming. Animal husbandry has been practiced in very small scale compared to

farming. Most farming activities in Zanzibar are rain fed *i.e.* depend on natural rainfall (seasons), but nowadays due to climatic change impacts many of them shifted to the irrigation system by using spring wells. In Zanzibar, farming is not only comprised of main crops (rice and cassava) but also cash crop (horticulture, cabbage, spinach, and tomatoes, watermelon) are well practiced.

## 2.2. Data and Its Processing

The study involves two types of data namely 1) primary data which is anecdotal information obtained through interviews and questionnaires of the extension officers and farmers at study sites of Kaskazini B, Kusini, Chake Chake and Micheweni; 2) secondary data which includes the watermelon production data (2014-2021) acquired from the Ministry of Agriculture Zanzibar and climate data (rainfall, maximum and minimum temperature records) acquired from TMA at Zanzibar offices with temporal coverage of 30 years from (1991-2020). The watermelon production and climate data were processed by using mean and standardized process. Also anecdotal responses were sorted (using excel sheets), calculated in monthly and seasonal averages, plotted and then analyzed.

## 2.3. Analytical Methods

These datasets were sorted and analyzed using the Statistical Packages for Social

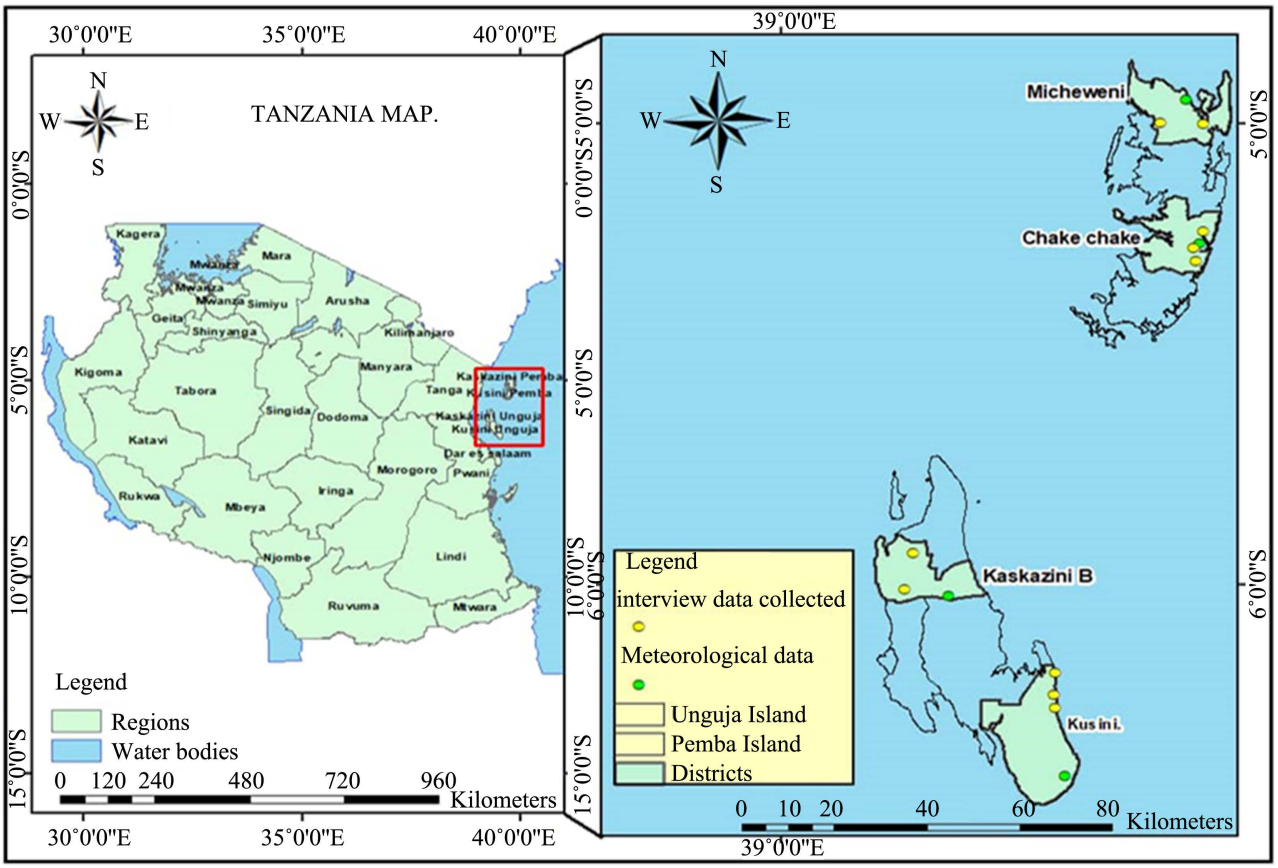



**Figure 1.** Map of Zanzibar Islands showing the location of study area.

Sciences (SPSS) and analysed using the Pearson correlation, which was used to find the association between watermelon production and climate parameter, and the paired t-test which was applied to show the significance of the mean difference of both water melon and climate parameters for the two periods of 2014-2017 and 2018-2021. Percentage changes were used to feature the extent to which the two affects each other. Also anecdotal responses were sorted (using excel sheets), calculated in monthly and seasonal averages, plotted and then analyzed.

## 3. Results

### 3.1. Climatology of Zanzibar

The results of the analysis of the annual and seasonal variability of maximum temperature (Tmax) in Zanzibar (Unguja and Pemba) presented in **Figure 2** (upper panel) reveals that the JJA Tmax is increasing at a faster rate (0.07˚C/yr) rate indicating an increase in the intensity of warming even at the colder months of JJA. Also the annual and seasonal (MAM) rates of increasing temperatures are at 0.6˚C/yr, while the increasing rates for the hotter month of October to

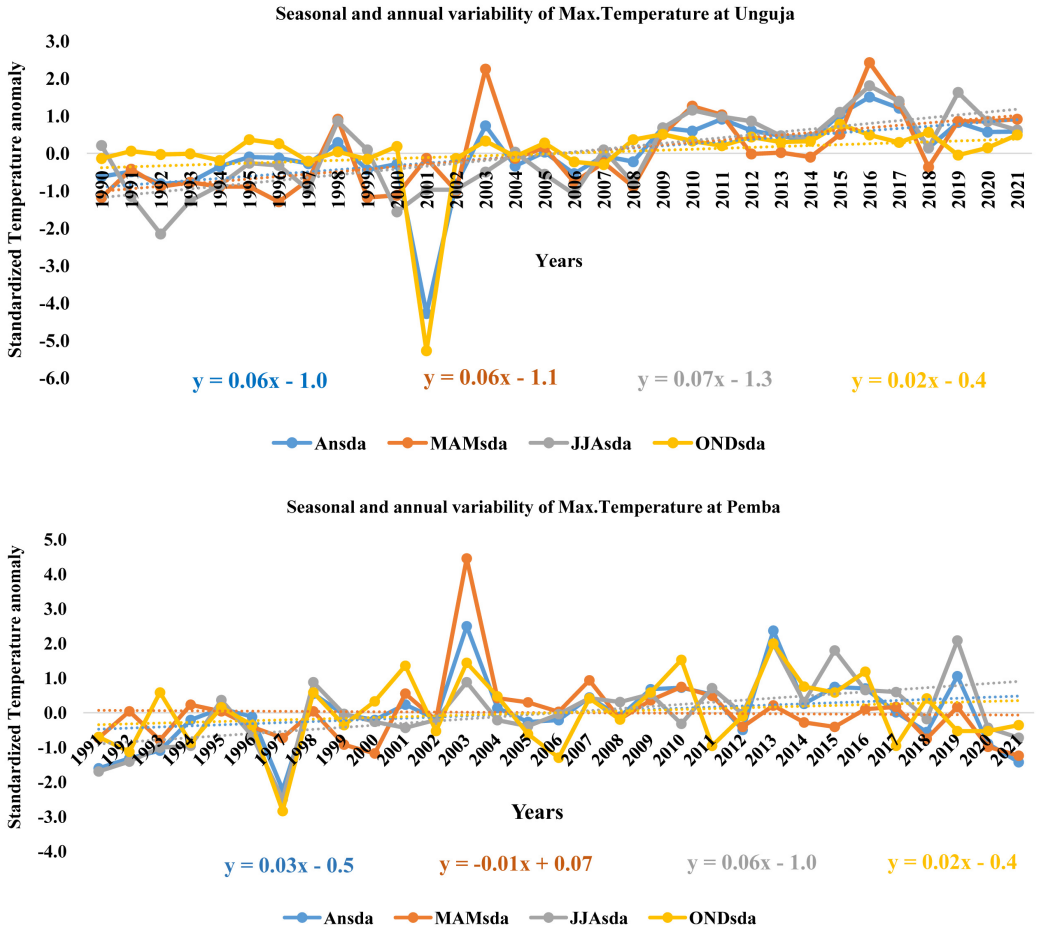



**Figure 2.** Inter annual and seasonal variability of Tmax for Unguja (upper panel) and Pemba (lower panel).

December (OND) is only 0.2˚C/yr, respectively. In general, the trend of seasonal and annual variability of Tmax is upwards, *i.e.* increasing with time. As for the annual and seasonal variability of Tmax in Pemba results in **Figure 2** (lower panel) shows that Tmax anomaly had the highest positive peak for all seasons (annual, MAM, JJA and OND) during 2003 and lowest negative peak of Tmax anomaly during 1997. Further results in **Figure 2** (lower pannel) shows that Tmax in Pemba was increasing at the fastest rate during JJA (0.06˚C/yr) followed by annual (0.03˚C/yr). Besides, results in this figure shows that from 2004 onwards most of the Tmax anomalies in Pemba were in positive direction. These results are in agreement with [6] which reported that the first decade of the 21st century was the warmest in records.

The results of the inter annual and seasonal variability of the Tmin for Unguja and Pemba presented in **Figure 3** shows that Tmin variability at Unguja (**Figure 3** upper panel) was characterized by negative anomalies for annual, MAM, JJA and OND effective 1990 up to 2002, but the shift to 2003 represents positive anomalies up to 2016 whereby during 2016, 2003 and 2010 shows the highest peaks (**Figure 3** upper panel), and during 2001 shows the lowest peak. For the year 2017 shows the negative anomaly to about −20˚C and positive anomaly from 2018 to 2022. In general unlike pristine days the minimum temperature from the late 21st century has been rapidly increasing indicating the increasing of

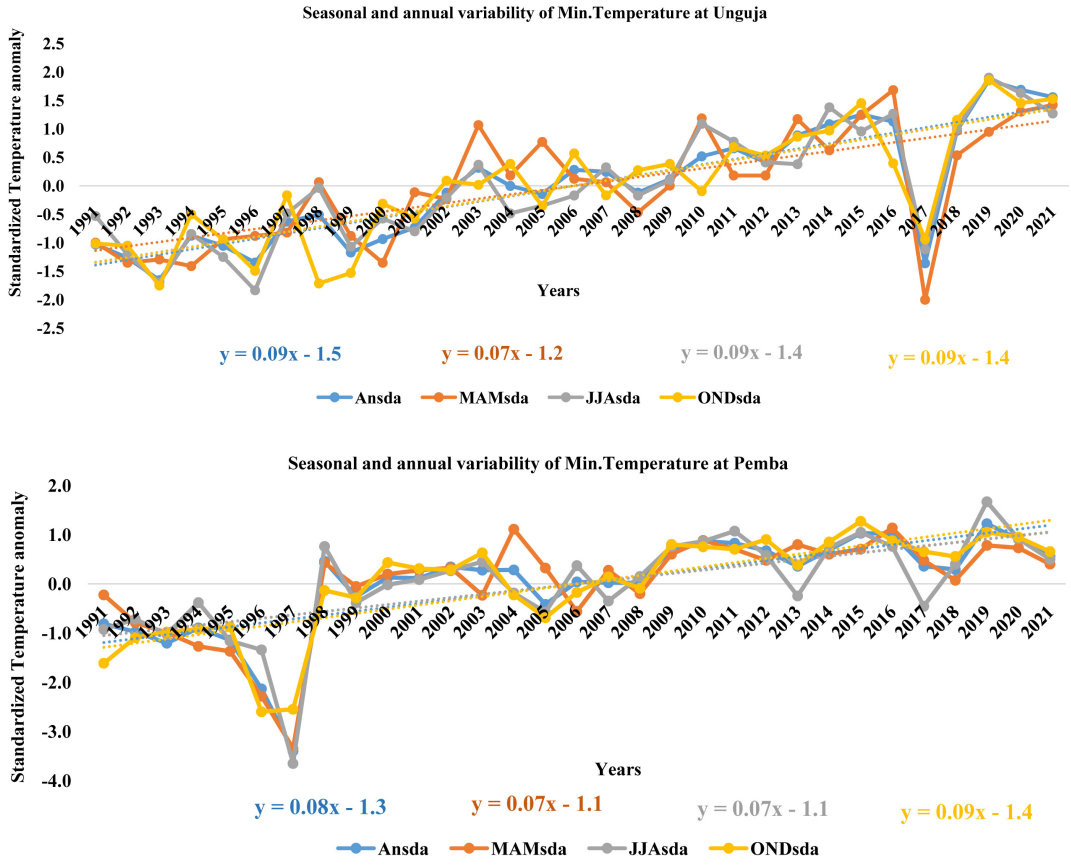



**Figure 3.** Inter annual and seasonal variability of Tmin for Unguja (upper panel) and Pemba (lower panel).

warm night days. The variability of Tmin at Pemba (**Figure 3** lower panel) indicates higher rates of increasing Tmin at 0.08˚C/yr, 0.07˚C/yr and 0.09˚C/yr for annual, MAM and JJA and OND, respectively. This result indicate higher increasing rates of Tmin in Pemba than in Unguja, the situation which could be explained by the fact that Pemba Island is located in deep ocean than Unguja Island. These results are in agreement with [7] who noted that the observed warming due to the increase of the minimum temperatures with little contribution from the daily maximum (daytime) temperatures.

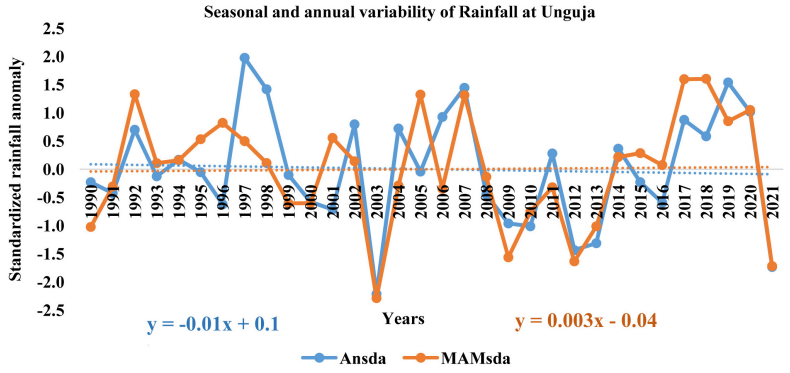
The results of the annual and seasonal rainfall variability in Unguja and Pemba presented in **Figure 4**, revealed that the rainfall variabilities in Unguja and Pemba have shown high and low peaks of rainfall anomalies in different years. The high rainfall peaks could be explained by number of meteorological and oceanographic factors including the strongest ever recorded El Nino event of 1997/1998, also for the higher peaks of 2019/2020 during OND could be explained by the occurrence of strong positive Indian Ocean Dipole (IOD) which was enhanced by the occurrence westerly propagating waves of convective cloud clusters known as Madden Julian Oscillations (MJO) as noted by [4]. The lowest rainfall peak of 2003 (**Figure 4(a)**) could be due to driest conditions in that last half century as noted by reference [8].

### 3.2. Community Awareness towards Watermelon Production

Watermelon farming in Zanzibar is practiced everywhere and by most of the peoples regardless of their age, gander, and even education level, this was well portrayed by the interview responses of different farmers on their farming sites or areas. These results are well supported by **Figure 5** and **Figure 6**, where by **Figure 5(a)** indicate that out of 72 respondents 83% were men and 17% are women, and for age results in **Figure 5(b)** reveals that 25% of the respondent aged below 30, while 62.5% were between 30 and 50 years and the 12.5% were above 50 years indicating that this farming activity is highly conducted by adults irrespective of their gender.

Moreover, results presented in **Figure 6(a)** reveals that of the watermelon farmers 51% (36) were primary school leavers, 40% (28) finished the secondary level, while 9% (6) graduated at tertiary level.

As for the understanding the people's awareness towards climate change results revealed more than 80% of the interviewers were aware on the existing changing climate of Zanzibar, and its four seasons which include Masika, Vuli, Kipupwe and Kiangazi. Also anecdotal results on climate awareness show that most of the peoples (80%) knows about the onset and cessation of the rainfall seasonal, and the differences in temperature between the last five years and now (**Figure 6(b)**), indicating that respondents were aware that the temperature have changed (increasing rate) for the last five years. This result is well agreed by the IPCC 4th report which noted that there an increasing of global air and ocean temperatures, and [4] who noted that the last decade of the 20th century and the first decades of the 21st century were the warmest periods in the world history.

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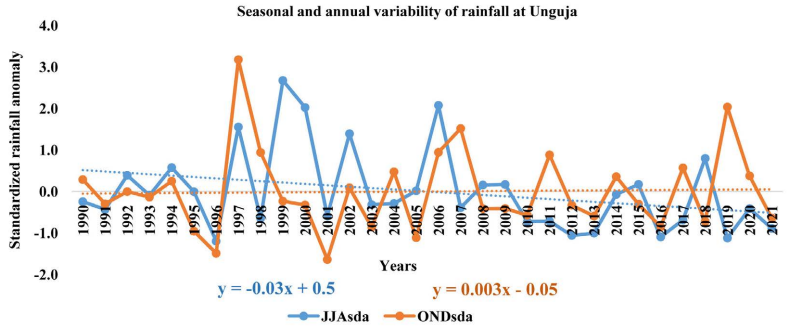


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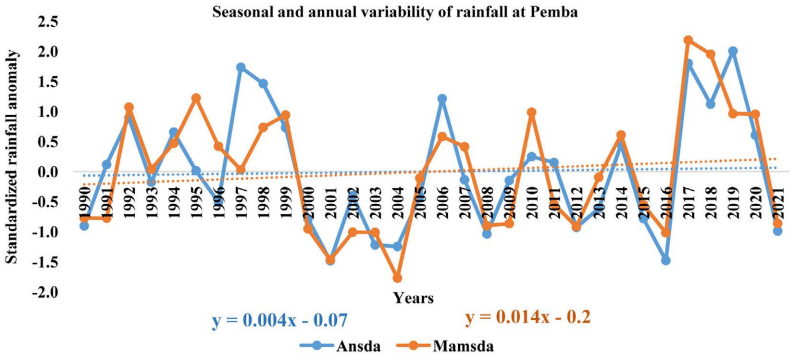


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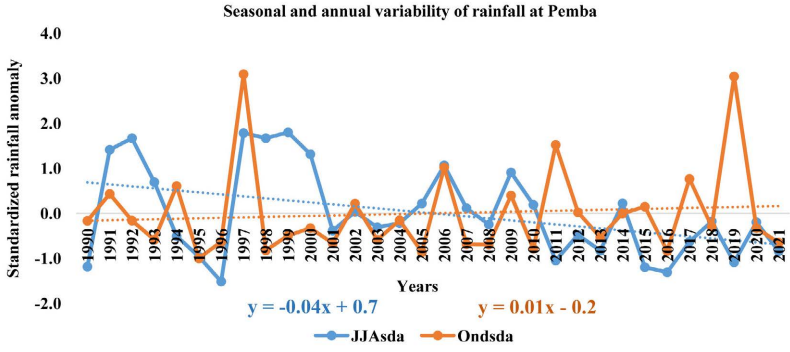
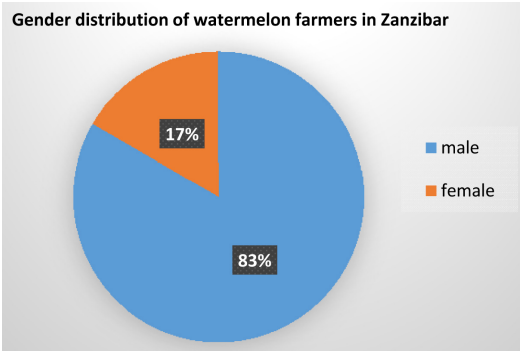



(d)

**Figure 4.** Inter annual and seasonal variability of rainfall for Unguja and Pemba). Note that the left panels are for annual and MAM, while the right panels are the JJA and OND rainfall variability, respectively.

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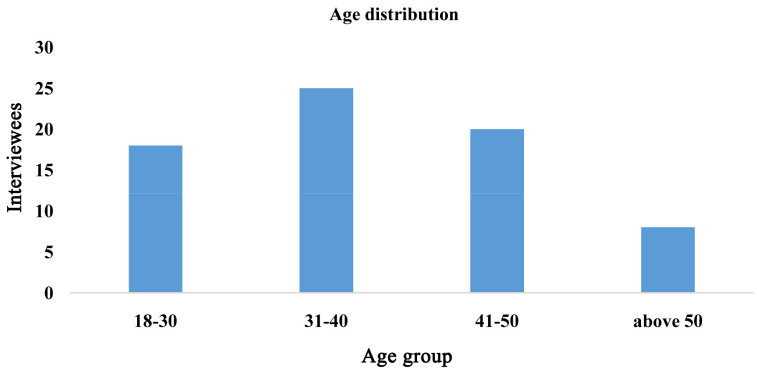
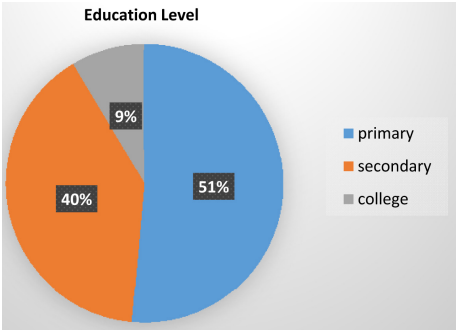



(b)

**Figure 5.** The interviewers' responses based on gender and age. Note that all the interviewed respondents practice the watermelon farming.

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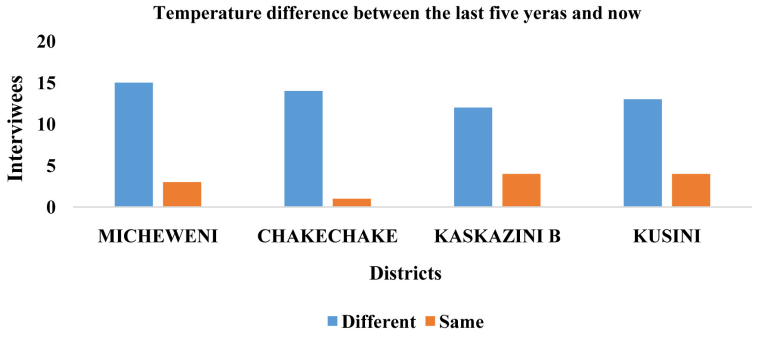


(b)

**Figure 6.** Education levels (a) and awareness (b) of watermelon farmer in Zanzibar.

### 3.3. Seasonal Variability of Watermelon Production in Zanzibar

The results of watermelon production in Zanzibar based on records of Ministry of Agriculture (Zanzibar) presented in **Figure 7** shows that watermelon production (yields) exhibits inter annually and seasonal variability, and this variability is not only dependent on fertilizers (e.g. composts), paste sides and farmers self-motivation, but also climate and weather fluctuations and changes seems to be most important production deciding factor. Since most agricultural activity in East Africa and Zanzibar in particular are climate driven [5] [9] [10] and also the agricultural activities in Zanzibar are also rain fed, therefore is highly threatened by the consequences of climate change, thus the watermelon production as an adaptive measure in Zanzibar is also subjected to seasonal variability (fluctuations). The 4th IPCC report noted that by 2020 in Africa all agricultural rain fed yields would be reduced by 50% due to the climate change stress as also noted by [11]. For instance, **Figure 7(a)** shows a small variation of watermelon production in Kaskazini B on seasonal scales, but in general the production trend seems to decline by approximate 402 tons/year. The results of the watermelon production in Kusini Unguja presented in **Figure 7(b)** shows inter annual improvement of watermelon production, with the exception of the year 2021 which had poor production. Also results shows that the production trend was increasing at approximately 73 tons/yr. As for annual and seasonal variability of the watermelon production in Pemba, results in **Figure 7(c)** shows a small increasing trend in Chake Chake of approximately 14 tons/yr, also during 2017 on this district the production was good as compared to other years. This could be due to fact that the 2017 OND rainfall was good with moderate intensity (**Figure 4(d)**), also presented high production is well agreed by [12] who noted that the optimal rainfall requirement for watermelon through the growing period ranges form 400 - 600 mm, this is agreed by the rainfall strength of 424 mm during OND 2017 in Chake Chake was while as compared 262, 294, 86, 200, 906, 193 and 125 mm of the other OND seasons. As for Micheweni district, results of the inter annual variability of the watermelon production (**Figure 7(d)**) shows that the production was quite annually good with an increasing trend of 176/yr.

### 3.4. The Influence of Weather or Climate Parameter on Watermelon Production (Quantity) in Zanzibar

The influence of weather or climate parameters on the production of watermelon in Zanzibar was analyzed using the Pearson correlation at $p \leq 0.05$. The results of the correlation for the 8yrs period (2014-2021) for Kaskazini B, Kusini, Chake Chake and Micheweni at degree of freedom (df) of 6 (note $df = n - 2$) presented in **Table 1**. The results of the influence of Tmax and Tmin variability on watermelon production presented in **Table 1** revealed that Tmax has higher association with watermelon production on Unguja island especially during OND for Kaskazini B ($r = 0.8$ at $p \leq 0.02$) and MAM for Kusini ($r = 0.5$ but not

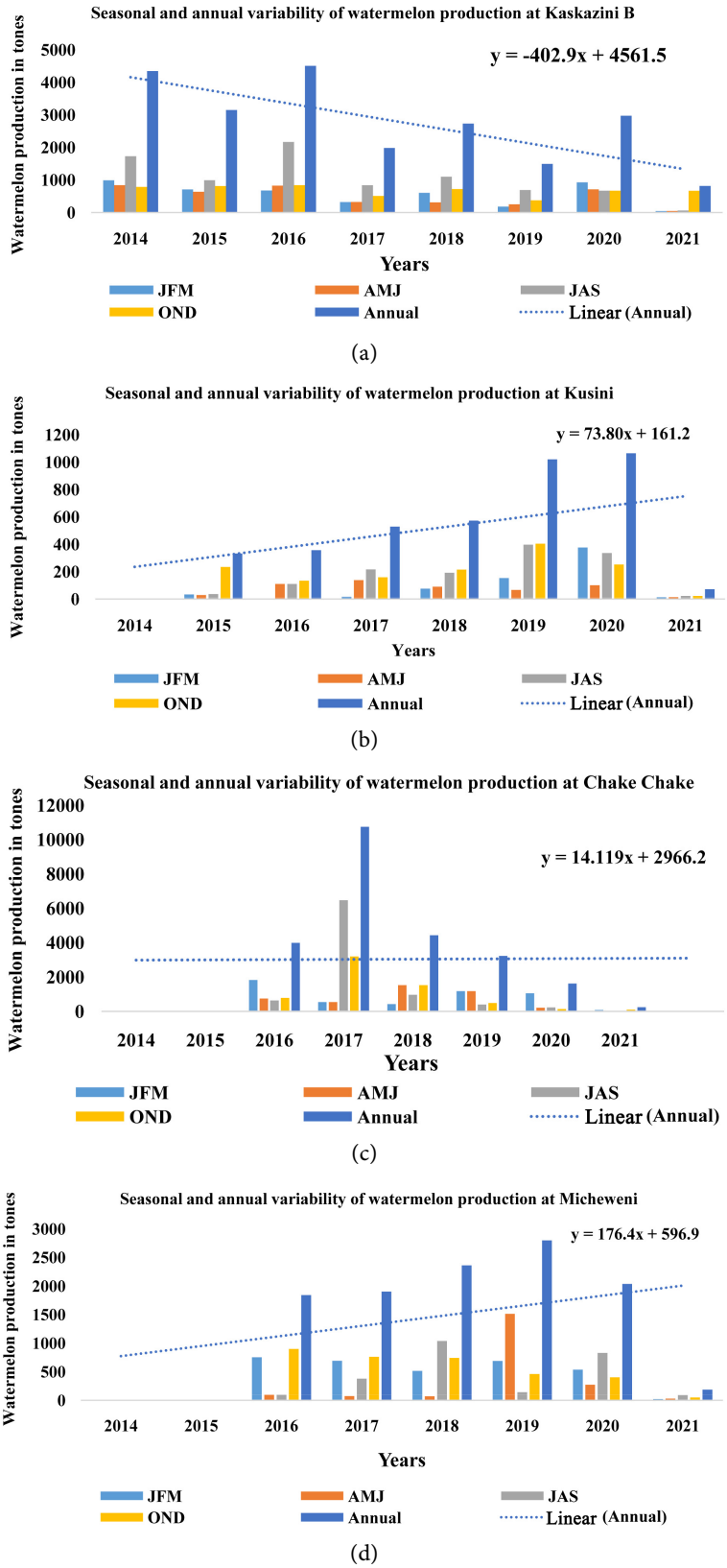


**Figure 7.** Inter annual and seasonal variability of watermelon production at Unguja and Pemba. Note that the left panels are the Kskazini B and Chake Chake and the right panels are Kusini and Micheweni.

**Table 1.** Results of the correlations (r) analysis and its significance (p) for watermelon production with weather parameters at Kaskazini B, Kusini, Chake Chake and Micheweni.

| Kaskazini B | Parameter | Correlation with Watermelons in Tones | | | | | |
|---|---|---|---|---|---|---|---|
| | | MAM | | JJA | | OND | |
| | | r | p | r | p | r | p |
| | Max. T | 0.1 | not sig | 0.2 | not sig | 0.8 | Sig ($p \leq 0.02$) |
| | Min. T | 0.3 | not sig | 0.04 | not sig | 0.03 | not sig |
| | RA | 0.2 | not sig | 0.2 | not sig | −0.9 | Sig ($p \leq 0.01$) |

| Kusini | Parameter | Correlation with Watermelons in Tones | | | | | |
|---|---|---|---|---|---|---|---|
| | | MAM | | JJA | | OND | |
| | | r | p | r | p | r | p |
| | Max. T | 0.5 | not sig | 0.3 | not sig | −0.4 | not sig |
| | Min. T | −0.5 | not sig | 0.10 | not sig | 0.30 | not sig |
| | RA | 0.4 | not sig | −0.1 | not sig | 0.7 | sig |

| Chake Chake | Parameter | Correlation with Watermelons in Tones | | | | | |
|---|---|---|---|---|---|---|---|
| | | MAM | | JJA | | OND | |
| | | r | p | r | p | r | p |
| | Max. T | 0.3 | not sig | 0.02 | not sig | −0.4 | not sig |
| | Min. T | −0.2 | not sig | −0.8 | sig | −0.55 | not sig |
| | RA | 0.5 | not sig | 0.01 | not sig | 0.1 | not sig |

| Micheweni | Parameter | Correlation with Watermelons in Tones | | | | | |
|---|---|---|---|---|---|---|---|
| | | MAM | | JJA | | OND | |
| | | r | p | r | p | r | p |
| | Max. T | −0.5 | not sig | −0.5 | not sig | −0.03 | not sig |
| | Min. T | −0.3 | not sig | −0.26 | not sig | −0.4 | not sig |
| | RA | 0.2 | not sig | 0.2 | not sig | 0.03 | not sig |

significant). These results are well supported by [12] who noted that for better performance of watermelon an optimal temperature that range from 22˚C - 28˚C is required, this temperature in very near to the mean OND Tmax (31˚C) for Zanzibar. Further results revealed that Tmin has good association with watermelon production during JJA on Pemba Island at Chake Chake ($r = -0.8$, at $p \leq 0.02$). These results indicate that Tmax during OND enhances watermelon production in Uguja, while JJA Tmin decline production in Pemba. These results for Pemba are in agreement with [13] who noted that cold stress reduces the watermelon production.

As for the influence of seasonal rainfall on watermelon production, results production in Table 1 reveals that, for Kaskazini B the MAM and JJA rainfall had weak positive correlation with watermelon production but not significant. Unlike MAM and JJA the watermelon production during OND season had strong negative ($r = -0.9$ at $p \leq 0.01$) with watermelon production. These results indicate that the production of watermelon do not favor the long and higher rainfall condition (e.g. the production had poor correlation with MAM rainfall Table 1), this result is highly supported by Figure 7 and Figure 8 which shows higher production during OND (which had poor spatial and temporal coverage of rainfall) and JJA which had less and unreliable rainfall but with low temperature rates. The correlation results for Kusini (Unguja) Table 1 reveals that there is good correlation ($r = 0.7$ at $p \leq 0.05$) between OND rainfall and watermelon production, implying that the increase in rainfall at Kusini results in higher production of watermelon. This could be attributed by the fact that OND rainfall is characterized by frequent dry spell which balances existing moisture to be good for watermelon growth. The results for the correlation between the water melon production and weather parameters shows that the MAM rainfall at Chake Chake district was high ($r = 0.5$) but not significant indicating that there exists little production of watermelon during MAM season as supported by anecdotal response Figure 8. Also this results in well supported by [5] who noted that the peak MAM rainfall for Pemba is during May and that of Unguja is during April indicating that the period between March and April for Pemba can be good for production of watermelon. Also results in Table 1 for Micheweni revealed a correlation of ($r = 0.2$ and $r = 0.03$), though not significant between watermelon production during MAM and OND, respectively. These findings are well supported by the anecdotal responses (Figure 8) which shows that about 67% of the total responses agreed that there exists higher production during OND, while 18% were in favor of JJA and only 5% were in favor of MAM. Besides, our study finding is well supported by [13] who noted that cold stress reduce production yield thus why our results has shown that production during OND was higher than during JJA, also our findings that no good production in MAM are in agreement with [14] who noted that growth of watermelon in dry season is very faster than wet season.

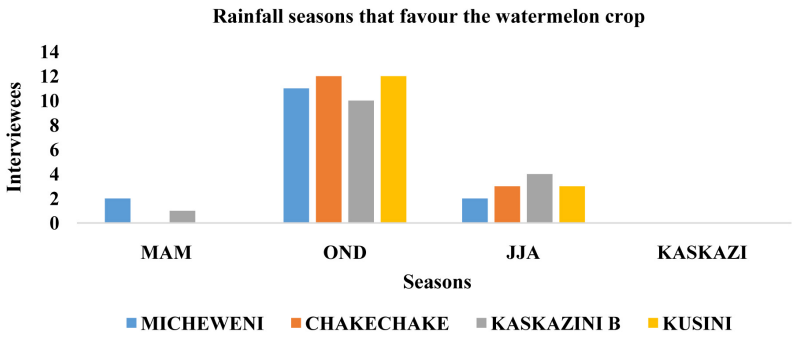


Figure 8. Rainfall season that favor watermelon production.

### 3.5. The Extent to which Climate Parameters Affects the Watermelon Production

The results of the paired t-test between the means of climate parameter and watermelon productions for the two periods presented in Table 2 for the four districts (Kaskazini B, Kusini, Chake Chake and Micheweni) shows that both limate parameters and watermelon production (tones) have rejected the null hypothesis (Ho) based on the significance/insignificance of stated p value (*i.e.* $p \leq 0.05$). This indicate that the alternative hypothesis (H1) that "there is significance difference between the means of both watermelon production and climate

Table 2. The significance level of climate parameter and watermelon production for the two stated period during MAM, JJA and OND seasons at Kaskazini B, Kusini, Chake Chake and Micheweni.

| KASKAZINI B | Parameter | ($p \leq 0.05$) | | |
|---|---|---|---|---|
| | | MAM | JJA | OND |
| | Tmax | 0.2 | 0.2 | 0.2 |
| | Tmin | 0.2 | 0.1 | 0.1 |
| | RA | 0.5 | 0.1 | 0.1 |
| | Tones | 0.1 | 0.04 | 0.1 |

| KUSINI | Parameter | ($p \leq 0.05$) | | |
|---|---|---|---|---|
| | | MAM | JJA | OND |
| | Tmax | 0.2 | 0.2 | 0.2 |
| | Tmin | 0.2 | 0.1 | 0.1 |
| | RA | 0.4 | 0.3 | 0.4 |
| | Tones | 0.5 | 0.1 | 0.2 |

| CHAKE CHAKE | Parameter | ($p \leq 0.05$) | | |
|---|---|---|---|---|
| | | MAM | JJA | OND |
| | Tmax | 0.1 | 0.2 | 0.1 |
| | Tmin | 0.2 | 0.2 | 0.3 |
| | RA | 0.3 | 0.4 | 0.3 |
| | Tones | 0.2 | 0.2 | 0.3 |

| MICHEWENI | Parameter | ($p \leq 0.05$) | | |
|---|---|---|---|---|
| | | MAM | JJA | OND |
| | Tmax | 0.1 | 0.1 | 0.1 |
| | Tmin | 0.2 | 0.2 | 0.3 |
| | RA | 0.4 | 0.1 | 0.2 |
| | Tones | 0.1 | 0.1 | 0.5 |

parameter for the two stated periods" was accepted. For instance, results of the paired t-test for Kaskazini B, Kusini, Chake Chake and Micheweni (Table 2) has p values greater than 0.1 for all season and for all parameters (*i.e.* rainfall, Tmax, Tmin and Tonage) except (JJA for Kaskazini B has p value of 0.04), indicating that there were significant changes of the watermelon production except during JJA season of Kaskazini B which accept the null hypothesis. It implies that the variability of climate parameter (Tmax, Tmin and RA) greatly influences the quantity of watermelon production in Zanzibar. In general, the results in Table 2 has shown that apart from other parameters (e.g. soil type, manures, paste sides among other which were considered to be constant in this study) the watermelon production (quantity) is highly affected by the variability of climate weather and parameters.

### The Percentage Changes in Watermelon Production

The presented results in Table 3 indicate the variability of the watermelon production within the seasons and places, was increased by 69% - 162% as well declining by a range of 17% - 77%. For instance, percentage change of watermelon production at Kaskazini B was declined by 49%, 55% and 17% during MAM, JJA and OND, respectively. Unlike Kaskazini B, the percentage changes in water melon production for Kusini was characterized by an increasing trend with the highest change of 162% during OND. As for Chake Chake district in Pemba Island its percentage change in watermelon production was increase by 129% during MAM, and declined by 77% and 43% during JJA and OND, respectively. These results are well supported by Figure 7 which shows that there is an annual decreasing trend of watermelon production in Kaskazini B, while for Kusini, Chake Chake and Micheweni the rate was at an increasing direction. The decline and increased percentage changes of watermelon production during OND and MAM at Chake Chake could be explained by the fact that the OND rainfalls starts at Pemba hence the whole period seems to be wet (declining the production), while the MAM rains starts at Unguja (peaks on April), and ceases in Pemba (with peak in May), leaving a wide room for production during March and April.

**Table 3.** The percentage change of climate parameter and watermelon production for the two stated period during MAM, JJA and OND seasons at Kaskazini B, Kusini, Chake Chake and Micheweni.

| Districts | Percentage changes in tones | | |
|---|---|---|---|
| | MAM | JJA | OND |
| Kaskazini B | −49 | −55 | −17 |
| Kusini | 0 | 69 | 162 |
| Chake Chake | 129 | −77 | −43 |
| Micheweni | 1020 | 342 | −0.5 |

## 4. Discussion

The study has investigated the influence of climate and weather parameters to the annual and seasonal production of watermelon in four districts of Zanzibar namely; Kaskazini B and Kusini for Unguja, Michweni and Chake Chake for Pemba. The secondary data consisting of 8 years dataset of watermelon production (tones) and rainfall, maximum temperature and minimum temperature was used to reveal the annual and seasonal variabilities, while the long term data of Tmax, Tmin and rainfall was used to characterize the climate of Zanzibar. The presented results have shown that both islands (Unguja and Pemba) were characterized by increasing Tmax at a rate 0.070˚C/yr during JJA, this indicate that there is an increasing warming events even during the colder months. As for hotter months results have shown an increasing rate 0.020˚C/yr. This increase of air temperature irrespective of the season (*i.e.* hotter or cold) could be explained by the fact that the first decade of the 21$^{st}$ century was noted to be the warmest in records and rapidly increasing of warm night conditions, as supported by [7] who noted that there are observed warming due to the increase of the minimum (night-time) temperatures with little contribution from the daily maximum (daytime) temperatures. Also the presented results show that there is higher increasing rate of Tmin in Pemba than in Unguja, in most seasons including MAM. This could be explained by the fact that Pemba Island lies in deeper ocean than Unguja Island, resulting into large amount heat released from the ocean to the atmosphere and then advected to the island as noted by [4]. On the other hand, the presented results in rainfall variability has shown that the annual and MAM rainfall increase by high rate in Pemba than in Unguja, while the same increment (0.02 mm/yr) in rainfall during OND was observed in all islands, and higher decreasing rates of JJA rainfall was observed in Unguja. In general, the presented results show an annual increasing trend of watermelon production through all districts except Kaskazini B with good production during OND followed by JJA and the least is during MAM season (**Figure 7**). These findings are well supported by number of studies including [4] [5] as well as respondents from different districts in Unguja and Pemba. Also the presented results are well agreed by [15] who noted that watermelon growth has low water requirement. Also the presented results in this study has shown that Tmax has higher association with watermelon production in Unguja Island especially during OND for Kaskazini B and MAM for Kusini, while Tmin during JJA has shown to decline watermelon production in Pemba especially at Chake Chake. These results are well agreed by [13] who noted that more cold stress might reduce production rates.

## 5. Conclusions

In regards to the stated specific objectives, hypotheses, analysis, the presented results and detailed discussions, the study concludes the following:

1) The climate of Zanzibar was found to be characterized by increasing warming trends for both colder and hotter months, with Pemba Island having

higher trends of increasing Tmin than in Unguja.

2) The societies in Zanzibar are aware of climate change impacts (e.g. onset and offset of seasons with increased frequency of severe weather events) and are highly adapting to these impacts through changing their agricultural practices such as engaging in watermelon production regardless of their age, gender and even education level.

3) The rainfall has a significant influence on the watermelon production. As for Zanzibar the study has found that high rainfall impact of watermelon production is on OND, followed by JJA and the last one is MAM.

4) Tmax has a higher association with watermelon production on Unguja Island especially during OND for Kaskazini B and MAM for Kusini while JJA Tmin declined production in Pemba especially at Chake Chake.

5) There is a significance difference between the means of both watermelon production and climate parameter for the two stated periods. This implies that the climate parameter (rainfall, Tmax and Tmin) has an influence on the watermelon production in Zanzibar.

6) Also the percentage changes in the mean production between two stated periods were calculated, and the results indicate that the variability of the watermelon production within the seasons and places was increased by 69% - 162% as well declining by a range of 17% - 77%.

## 6. Recommendations

In regards to the presented results discussion and conclusion, the study recommends the following:

1) Climate of Zanzibar seems to increase warming for both colder and hotter months, thus mitigation programs for reducing the climate change impacts on agriculture should be designed.

2) OND rainfall season is preferred for this crop, because the productions of watermelon do not favor the long and higher rainfall condition.

3) Weather forecast information is important before practicing this crop.

4) Apart from the presented findings other issues including pest sides, fertilizers, soil characteristics and moisture which are more important for reducing fungus should be researched for smooth growth of watermelon.

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## Conflicts of Interest

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

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