# Temporal Rainfall and Temperature Trends, Impacts in Agriculture and Adaptations that Respond to Local Conditions *A Case of Mvomero District, Tanzania*

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**Abstract**

This study assessed on the existing trends of rainfall and temperature in Mvomero and Makuyu villages in Mvomero District. Furthermore, it assessed the impacts of rainfall and temperature variations on crop production and identify the adaptation strategies that respond to local condition. Both primary and secondary data were used. A sample size of 7% of the total households was sampled for the study. The findings of this study show that the increasing temperature, erratic rainfall and highly varried rainfall reduces crop yields. This state of crop yields has been evidenced from the trends both at national and local level. Moreover, the study has expressed the status of food security in the area. Lastly, the study has recommended potential strategies that responds to specific needs of the local conditions.

**Keywords:** rainfall variability, wet spells, crop production, food security.

## 1. Introduction

Mvomero is one of the six districts of Morogoro region in Tanzania. It covers an area of about 14,0042km$^2$. It is located between latitudes 05$^o$ 80′ and 07$^o$ 40′S and between longitudes 37$^o$20′ and 38$^o$ 05′E and lying between 300 to 400m above the sea level. The study was conducted in two villages namely Mvomero and Makuyu. The annual rainfall is variable depending on the altitude. About 800 to 1000 milimetres of rainfall are received near the coast while in the inland areas towards Dodoma and north of the Wami Sub-Basin the average rainfall is between 500 to 600 milimetres per year (Mkonda, 2012). Crop production in the area is based on maize, rice and sorghum. On the other hand, livestock keeping is mainly done by the pastoralist societies especially the Masai.The area is divided in two agroecological zones which include flood plain at the lowland and dryland at the highland, hence the earlier being a high potential area and the latter being the low potential area.

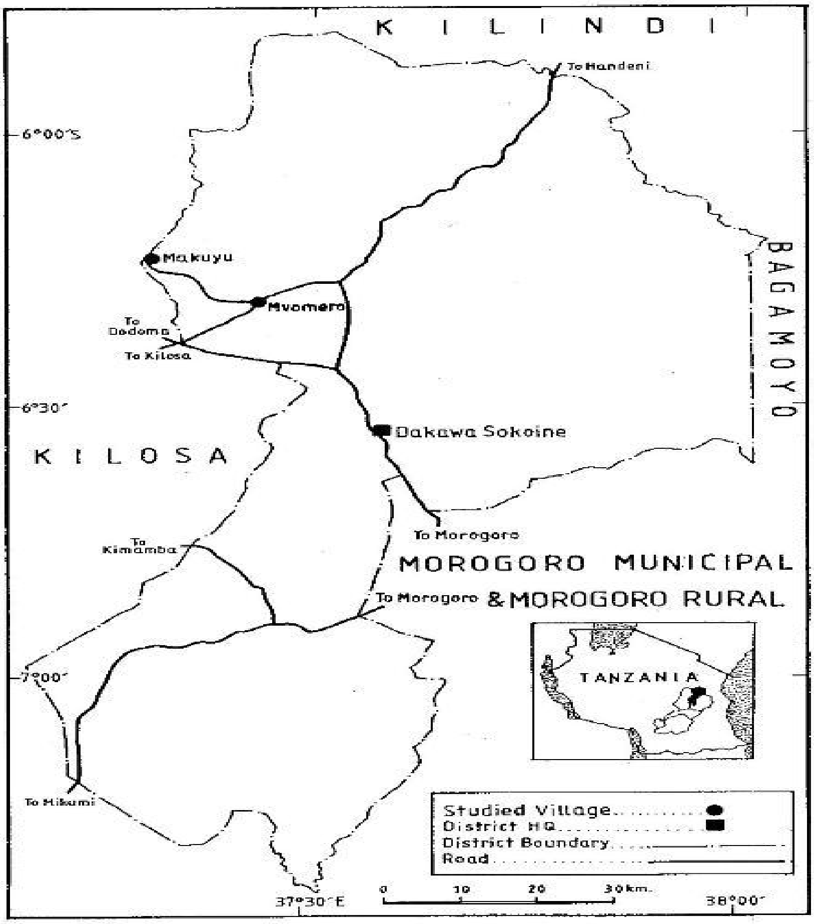


**Figure 1:** A Sketch Map of Mvomero District

**Description of Agriculture in Mvomero District**

Crop production is the key economic activity in this area. The cultivation of sugarcane, rice, maize and sorghum is more predominant as shown in Table 1.. Livestock keeping is also carried by some pastoralists living in this area. Therefore, the major household livelihood activity in the study area is agriculture. Agriculture is more dominant in areas with alluvial plains especially the Wami Sub-Basin. In areas with drainage systems, large and small scale irrigation is applied especially around the Mvomero, Wami Sub-Basin and their tributaries such as Mkondoa, and Divue rivers which are tributaries of Wami Sub-Basin (Hyera, 2007). Other significant livelihood activities in the area are hunting, bee keeping, charcoal making and fishing (Madulu, 2005).

Table 1: Key Crops Grown in Mvomero District (2008/2009)

| Crops | Planted area (hectares) | Average yield (tones) |
|---|---|---|
| Maize | 26,626 | 47,291 |
| Rice | 13,725 | 34,313 |
| Sorghum | 12,694 | 28,562 |
| Cassava | 19,725 | 59,206 |
| Beans | 12,714 | 8,264 |
| Sugarcane | 10,095 | 403,800 |
| Banana | 31,200 | 31,200 |
| Vegetables | 2,041 | 51,020 |

**Source**: DALDO; Mvomero District, 2011

**2. METHODOLOGY**

**Data Collection Procedures**

**Sampling Design, Procedure and Sample Size**

The sampling unit for this research was a household. Both random and purposive sampling were employed in selecting both the study area and/or sampling units (Gill ham, B. 2000). Random sampling was used to select one ward out of 17 wards as a preliminary stage of sampling. Likewise, random sampling was used to select

 

Mvomero and Makuyu villages among the villages in Mvomero ward. Purposive sampling was used to select two sub-villages from each village. Geographical location, time, financial constraints, transport and communication networks were factors considered in the selection of these sub-villages. The sample size of 7% of the total households was sampled for the study. Purposeful sampling was also employed for respondents at ward distict level. Thus, 20 households were randomly sampled from each sub-village to ensure that every household had equal chance to be selected for the study.

A household was taken as a group of people who eat from a common pot, sharing the same house and may cultivate the same land (Njana, 1998). According to Tanzania National Census of 1988 a household is the arrangement made by persons individually or in groups for providing themselves with food and other essentials for living or a group of persons who live together and share expenses.

Key informants in this study involved Village Executive Officer (VEO), Ward Executive Officer (WEO), District Executive Office (DEO), District Agricultural and Livestock Development Officer (DALDO), Agricultural Extension Officers, elders and meteorological station officers for Kongwa and Kinyasungwe stations in Dodoma region.

Data were analyzed using Statistical Package for Social Science (SPSS).

## 3. RESULTS AND DISCUSSION

### Seasonal Rainfall Trends

Results of the mean annual rainfall in the study area from 1990 to 2010 are presented in Figure 5 below. The mean annual rainfall patterns appear to decrease at a non-significant rate of $R^2=0.0207$. The findings show that the mean annual rainfall has been fluctuating overtime at a decreasing trend. Both temporal variability and decreasing rainfall pattern pose effects on the environment and affect negatively the biodiversity of the area. Similarly these findings (decrease in rainfall) are further supported by the information from the socio-economic survey done in the study area through household questionnaire. About 70% of the respondents reported that rainfall has been decreasing overtime. Thus, the findings (Figure 5) showing the decreasing trend of the mean annual rainfall in the study area also reflect the peoples' perception on the trend of rainfall.

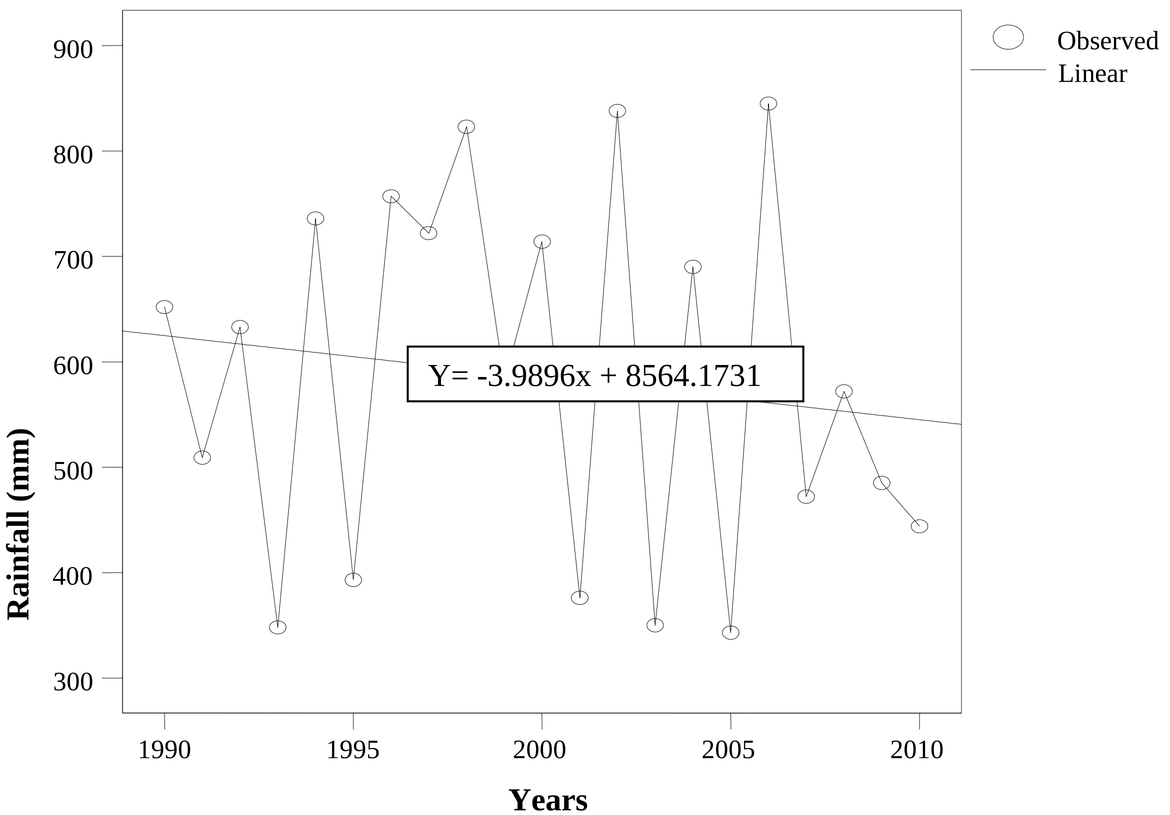


**Figure 2:** Mean Annual Rainfall from 1990 to 2010 at Kongwa Meteorological Station
**Source:** Kongwa Meteorological Station, 2011

Analysis in Figure 2 above show that the trend based on mean annual rainfall data provide general impression which may not capture actual situation on the ground particularly on droughts and associated crop failures in the field. To depict the actual situation, particularly the dry spells and their associated implications during the growing season, it is important to focus on monthly and daily rainfall trends for February, March and April which constitute the growing season as shown in Figure 3 and 4 below.

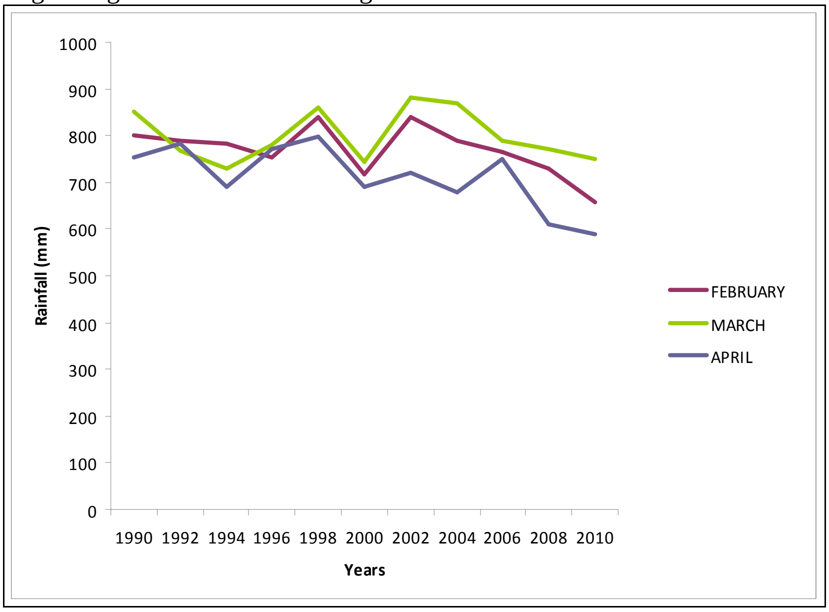


**Figure 3:** Rainfall Variability for; February, March and April in the area from the Year 1990 to 2010.
**Source:** Kongwa Meteorological Station, 2011

Results in Figure 3 above show monthly rainfall trends for February, March and April for the past twenty years. The three months show temporal fluctuations of rainfall at a declining trend. These temporal trends are viewed in phases as follows: between 1990 to 1995 there was a decreasing trend of rainfall in all three months. This was followed by an increasing trend between 1996 and 2000 and from 2000 to 2005. Lastly, from 2006 to 2010 these months experienced a decreasing trend. These findings were also supported by the farmers (respondents) as about 70% of the respondents reported that rainfall has been decreasing overtime.

Since analysis of rainfall distribution in Figure 3 for the three months was general, and since crops seem to flourish well in months with abundant days of rainfall than those with few days of rainfall, then further analysis of rainfall distribution in each month is very important in order to reflect the real situation on crop production. Therefore, Figure 4 below illustrates this situation as it looks on the number of wet spells.

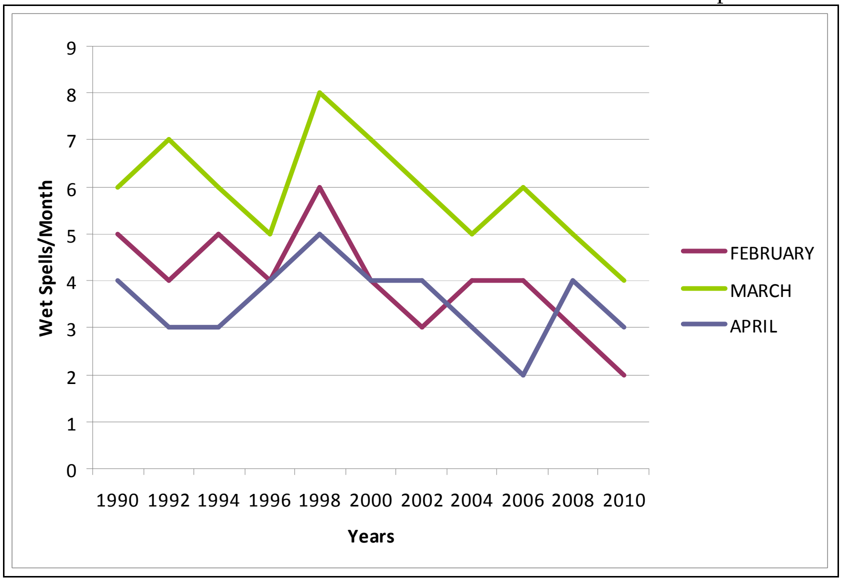


**Figure 4:** Number of Wet Spells per Month in the Study Area during the Growing Seasons from the Year 1990 to 2010
**Source:** Kongwa Meteorological Station, 2011

Research findings show that the trends of wet spells within a month are not uniform, but they fluctuate over time (Figure 4). Due to these fluctuations, the area can record poor crop production while in actual fact the amount of rainfall was high. This is because within a month, the area can receive unfair distributed wet spells as more wet spells are experienced when crops are already affected adversely by drought. This perception can be difficult to comprehend among the farmers because their general perception is that; when the number of wet spells is high then the crops will also grow well and the vice versa (Liwenga, T. 2003). However, their perception overlooks the distribution patterns of wet spells within a month. Thus, in favour of crop production, available wet spells need to be fairly distributed within a month during the growing season. Thus, fair distribution of wet spells is very important as it ensure the sustainability of wet on the ground. On the other hand, heavy rainfall with few wet spells in the growing season might have no favour to crop production because it occurs with fewer wet spells while crop production is favoured by numerous and fairly distributed wet spells.

Therefore, it is not surprising to observe the situation of crop failure in the presence of large amount of rainfall and a large number of unfairly distributed wet spells. Using Figure 3 and 4 above, an attempt is made to further analyse both rainfall intensity and number of wet spells in each of the three months in order to reflect the real situation in the study area. Therefore, hereunder is the discussion based on the relationship between the amount of rainfall and the number of wet spells for February, March and April..

**February**

In February there are evidences that usually the amount of rainfall is high (Figure 3) while the number of wet spells is low (Figure 4). To support this argument, both Figure 3 and 4 show that in 1996 and 2002 the total amount of rainfall was high while the number of wet spells was low and at the same time crop production was poor as seen in Figure 8 below. Crop production was poor because of fewer number of wet spells. These findings was supported by the farmers in the study area as about 80% of respondents said that 1996, 1998 and 2002 were among the years which experienced very low crop yields and subsequently food insecurity due to severe drought.

**March**

The study area experiences more rainfall (Figure 3) and increased number of wet spells (Figure 4) at a fluctuating trend in March compared to February and April. However, the temporal fluctuations in the amount of rainfall (Figure 6) and number of wetspells (Figure 4) also do not occur in the same pattern in this month. Hence, high rainfall does not necessarily correlate with high number of wet spells and the vice versa. For example, in 1992 there was a decrease in the amount of rainfall (Figure 3) while the number of wet spells (Figure 4) was at maximum, hence the situation led to better yields. This is supported by information from PRAs survey done in the study area as about 70% of the respondents said 1992 was among the good years in terms of crop yields. Likewise in 2006, there was a decrease in the amount of rainfall with increased number of wet spells which subsequently favoured crop production.

**April**

April marks the end of the growing season. It is a time when most of the crops get matured. During this month, the total amount of rainfall (Figure 3) and number of wet spells (Figure 4) seem to have no direct correlation. For instance, in 1996 and 2002 there was high rainfall with fewer numbers of wet spells as it rained thrice within the month. This trend was also supported by farmers through PRAs as about 80% of respondents said that 1996 1998 and 2002 were among the bad years as they experienced very low crop yields and subsequently led to food insecurity due to prolonged drought. Therefore, the fewer the number of wet spells, the poor the crop produced and subsequently food insecurity.

***Seasonal Temperature Trends***

Temporal temperature pattern in the study area is fluctuating at an increasing trend. Results presented in Figure 5 below show seasonal fluctuation at an increasing trend of the mean annual temperature from 1990/1991 to 2009/2010. The temperature patterns appears to have increased significantly at the rate of $R^2$ =0.02289. These findings were supported by the farmers as 97.5% of the respondents said temperature is increasing in the area. Therefore, temperature in the study area has shown pronounced changes overtime.

 

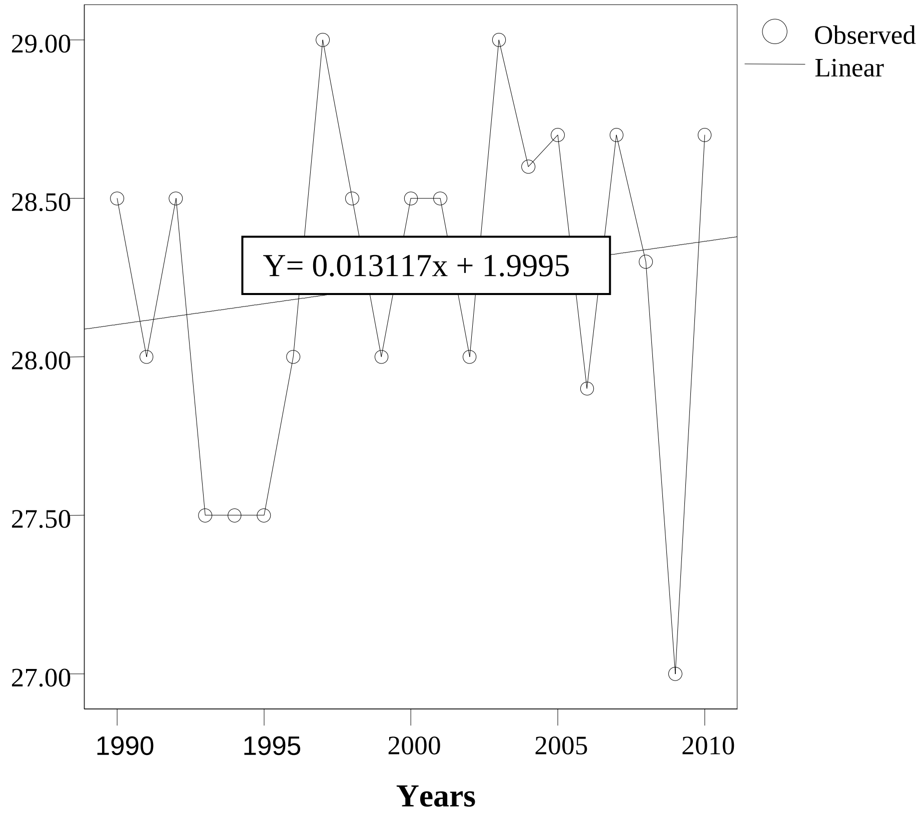


**Figure 5**: Mean Annual Temperature (1990 – 2010) at Kinyasungwe Hydromet Station
**Source:** Kinyasungwe Hydromet Station, 2011

However, the above trend of the mean annual temperature presented in Figure 5 is too general; it does not tell much on the months of the growing season (February, March and April). Therefore, there is a need to establish a figure which reflects this trend. Hence, Figure 6 below describes this trend with a major focus on February, March and April.


**Figure 6**: Temperature Variability for; February, March and April in the Study Area from the Year 1990 to 2010.
**Source:** Kinyasungwe Hydromet Station, 2011

Although rainfall does not seem to have changed significantly, temperature shows pronounced changes overtime. The increase in temperature has increased evapo-transpiration on the ground and hence loss of soil moisture and subsequently drought, thus affecting negatively crop production. Evapotranspiratiom is more dreadful during the season with severe drought.
Figure 6 above depicts that the trends of temperature for February, March and April from 1990 to 2010 have been fluctuating overtime at an increasing trend. For example; from 1990 to 2000 the trends of temperature in

 

the study area experienced an increasing trend while in 2002 temperature experienced a sharp decrease. Also, another increasing trend was experienced from 2002 to 2010.

This trend was supported by the farmers in the study area as about 97.5% of the respondents said that temperature has been increasing overtime. The farmers have used some environmental stresses such as increased heat and drought in their areas to detect that temperature is increasing. Therefore, the increasing temperature has adverse impacts on crop production in the study area due to increased evapotranspiration and subsequently loss of soil moisture.

In short, the trends of rainfall in Figure 3 and that of temperature in Figure 6 show that whenever there was a decrease in rainfall, also there was an increase in temperature. Hence, the general temporal trend of rainfall is inversely proportional to that of temperature.

***Trends of Crop Production***

***"Trend of Crop Production at the National Level"***

Tanzania is an agricultural country (URT, 2007). The country engages in crop production particularly food crops such as rice, maize, sorghum, potatoes, banana, cassava and millet. The type and amount of food produced in the country depends on a number of factors such as availability of agricultural inputs, the nature of agro-ecological zones and the impacts of climate change and variability (IPCC. 2007a&b). The production trends of key food crops such as maize, sorghum and rice at national level are presented in Figure 7 below. The amount of crops produced is expressed in tons per hectare.

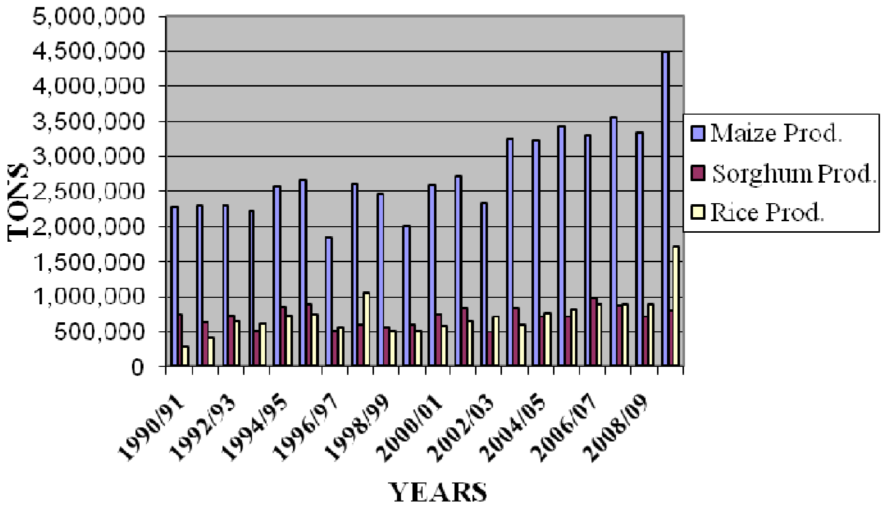


**Figure 7**: Rice, Maize and Sorghum Production at National Level (1990- 2010)

**Source:** URT, 2010

The trends of rice, maize and sorghum are fluctuating overtime. The production trends of these crops at national level do not differ from that of the study area.

***"Trends of Crop Production in the Study Area"***

Results from respondents in the study area shows that the production trends of key crops such as rice, maize and sorghum are fluctuating overtime. The fluctuation patterns of these crops are relatively similar to that of the national level. Hereunder is a brief description on the trends for rice, maize and sorghum.

**Trend of Rice Production in the Study Area**

Results show that rice is one of the significant crops cultivated in the area because it is both a staple food crop and cash crop for most farmers. However, 77.5% of the respondents reported that rice yield is decreasing overtime due to severe drought. On the other hand, 22.5% of the respondents reported a fluctuating trend of the crop over time. Meager yields of food crops are likely to lead to food scarcity and subsequent food insecurity in the study area.

**Trend of Maize production in the Study Area**

Maize is another dominant food crop in the study area. The crop is grown in large part of the study area because it is somehow a drought resistant crop compared to rice. The crop is grown in both highland and lowland zones while rice is mainly grown in valleys and lowland areas where water is reliable. As a response to the impacts of climate change and variability (CC&V) on crop production, 82.5% of the respondents said that the production trend of the crop is decreasing over time due to severe drought while 17.5% said it is fluctuating. The decrease in maize yields threatens food security since it is a staple food crop for the people in the study area.

**Trend of Sorghum Production in the Study Area**

Sorghum is another dominant crop in the study area. It is the most drought resistant crop adopted as a measure towards adapting to excessive drought caused by the impacts of climate change and variability (CC&V). However, 76.3% of the respondents said that regardless of being drought resistant crop, the trend of sorghum production is decreasing overtime due to severe drought while 23.7% said the trend of the crop is fluctuating. The decrease and fluctuation of this crop happens as a result of the occurrence of excessive drought in the area. Thus, the decrease in sorghum yields lead to food scarcity and subsequent food insecurity in the study area. Also, the information from the DALDO of Mvomero District support the trends of these crops in the study area as they indicate that; the production trends of rice, maize and sorghum have been fluctuating overtime at a decreasing trends. For example; in 2000/2001 and 2001/2002 the production trend of these crops was at peak while in 2003/2004 these trends experienced a significant fall. Another peak was experienced in 2007/2008 with a remarkable fall in 2009/2010. According to PRAs survey; erratic rainfall and increased temperature are the cause of these trends (URT, 2010). Figure 11 below shows the trends of maize, rice and sorghum production in time series from 1997/1998 to 2009/2010 in the study area. The amount produced is shown in tons per hectare.

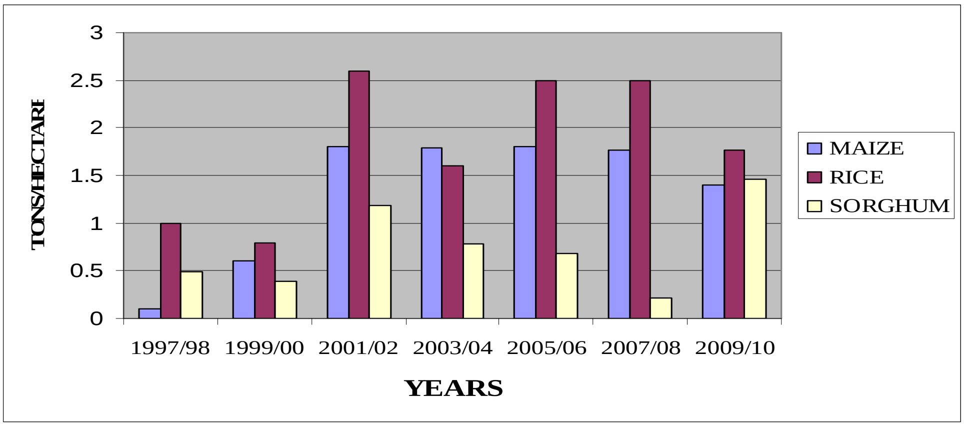


**Figure 8**: Key Crops Expressed in Ton per Hectare in Mvomero District (1990 – 2010)
**Source:** DALDO; Mvomero District, 2011

The trends imply that better crop yields ensure food security while poor yields may lead to food insecurity in the area. Hence, stable trends of food crop production kept at maximum will ensure food security in the area.

At both local and national levels these fluctuations are caused by a number of factors including the impacts of climate change and variability. Therefore, these impacts in turn are likely to affect adversely the production of food crops in the study area.

***Linking Temporal Rainfall and Temperature Trends and Crop Production***

The adverse impacts of climate change and variability have posed a dreadful condition to crop production at both national and local level. Results show the fluctuating trends of crop production particularly maize, rice and sorghum. Similarly, the trends of both rainfall (Figure 3) and that of the crops in the study area (Figure 8) have been fluctuating overtime in a similar pattern. Also, the increase in temperature has increased evapotranspiration to already affected areas (areas with severe drought) . The following sections describe the impacts of climate change and variability on crop production in the study area by viewing at rainfall (Figure 3) and temperature (Figure 6).

**Rainfall**

Rainfall is the most important element for crop production. The research findings show that rainfall has been fluctuating overtime in the similar pattern to that of crops.The decrease in rainfall has reduced the production of crops in the study area. In this remark, drought has adverse effect to the production of food crops.

The findings show that in years when rainfall was little during the growing season, crops yield was also minimal. This was supported by the information from DALDO through interview as he said that severe drought is a major factor for crop failure in the district. Furthermore, the decrease in crop yield always lead to food insecurity among the people in the community. Furthermore, the findings show that the temporal trends of both rainfall (Figure 3) and crop production (Figure 8) have been fluctuating together in a roughly similar pattern. Hence, there is a positive correlation between these two variables.

Therefore, rain scarcity in the area has affected adversely the production of crops. Also, the farmers in the study area supported these findings as about 90% of respondents reported that prolonged drought is the major problem for crop failure. Furthermore, they said that the production of maize, rice and sorghum have been decreasing overtime due to excessive drought.

In February there are evidences that usually the amount of rainfall is high (Figure 3) while the number of wet spells is low (Figure 4). To support this argument, both Figure 3 and 4 show that in 1996 and 2002 the total amount of rainfall was high while the number of wet spells was low and at the same time crop production was poor as seen in Figure 8 above. Crop production was poor because of fewer numbers of wet spells. This was supported by the farmers in the study area as about 80% of respondents said that 1996, 1998 and 2002 were among the years which experienced very low crop yields and subsequently food insecurity due to severe drought.

On the contrary, in 2004 the amount of rainfall was low but the number of wet spells was high (Figure 3 and 4) and crop production was better (Figure 8). This was also supported by the farmers from both Makuyu and Mvomero villages who reported through focus group discussion that 2004 and 2006 were better years for them as they got better crop yields. This means that, despite the decline in the amount of rainfall; the increased number of wet spells which were probably fairly distributed have favoured crop production in the study area.

Also, in 1992 there was a decrease in the amount of rainfall (Figure 3) while the number of wet spells (Figure 4) was at maximum, hence the situation led to better crop yields. This is supported by information from PRAs survey done in the study area as about 70% of the respondents said 1992 was among the good years in terms of crop yields. Likewise in 2006, there was a decrease in the amount of rainfall with increased number of wet spells which subsequently favoured crop production.

This implies that crop production was better as a result of increased number of wet spells. This was further supported by the farmers from both Makuyu and Mvomero villages through focus group discussion as about 70% said that 2004 and 2006 were better years for them as they earned better yields. The reason behind better crop yields was due to fovourable rainfall received in the area. However, in 1996 and 2002 there was an increase in rainfall amount while the number of wet spells was declining. As a result; this condition affected negatively crop production. Also, this was supported by the farmers in the study area as about 80% of respondents said that 1996, 1998 and 2002 were among the years which experienced very low crop yields and subsequently food insecurity due to prolonged drought. Again, in 2006 there was also fewer number of wet spells as it rained twice within the month. Thus, basing on the results above; the fewer number of wet spells in the study area has contributed to poor crop production.

However, in 2008 there was a decrease in the amount of rainfall with the increase in the number of wet spells. Thus, the increase in the number of wet spells favoured crop production in the study area. This finding was supported by the information from the Mvomero-DALDO which shows that the District increased the production of food crops from 155,063 tones in 2007/2008 to 239,034 tones in 2008/2009 while the size of the cultivated area was almost the same, hence this is an increase of about 54%.

Also, this study reveals that in 2010 both the trend of amount of rainfall and number of wet spells experienced a sharp decline. This has adverse affects on the production of food crops (Figure 8) in the study area due to decreased number of wet spells.

**Temperature**

Analysis of the field data indicates that temperature has been increasing significantly in the study area. In connection to that, 97.5% of the respondents said that temperature has been increasing in the area. The increase in temperature increase drought due to increased evapotranspiration to already affected areas (areas with severe drought). Subsequently, this situation reduces soil moisture which could help crop production (Paavola J. 2006). Therefore, the increase in temperature in the area has affected crop production more adversely especially in areas with severe drought. This situation leads to fluctuations in crop yields and subsequently food insecurity. This is supported by the farmers as about 90% of the respondents reported that severe drought caused by both decrease in rainfall and increase in temperature has affected crop production in their areas and subsequently leads to food insecurity.

Therefore, the trends of crop production and those of variability in rainfall and temperature show that there is close association among these aspects. In years when there was decrease in rainfall and increase in temperature, crop yields were also poor. For example, the season of 2002/2003 had rainfall shortage, increased temperature and reduced crop yields. Again, in the season of 2007/2008 there was an increase in temperature, decrease in rainfall and poor crop yields. Furthermore, in recent season (2009/2010) there was an increase in temperature, decrease in rainfall and reduced crop yields. Therefore, basing on the above trends, it is now argued that there is a correlation between the variability in rainfall and temperature, and the trend of crop production in the study area. The decrease in rainfall with the increase in temperature lead to reduced crop harvests. Poor crop harvest lead to food insecurity especially to poor families which can not afford food expenses (to buy food).

***Farmers' Response to the Impacts of CC&V in the Study Area***

As a response to the impacts of CC&V, farmers have established some adaptation measures and coping mechanisms in order to reduce these impacts (Paavola J. 2006). About 75% of the respondents reported that they reduce the number of meals as a coping mechanism especially in January, February and March when food shortage is very severe. Also, over 85% of the respondents reported that they have abandoned rice production as a result of excessive drought in the area (Olmos, S. 2001). In addition, farmers have adopted new crops as a response to the impacts of CC & V. Some of the dominant crops adopted included: cassava, sorghum, maize, sunflower and "*ufuta*". The level of adoption of these crops varies from one area to another depending on location, labour, technology and ecology. Table 4 below gives a summary of these crops.

Table 4: Adopted Crops in the Study Area

| Adopted Crops | N=80 |
|---|---|
| "Ufuta" | 12.5 |
| Cassava | 22.5 |
| Maize | 38.8 |
| Sorghum | 25.0 |
| Sunflower | 1.2 |
| Total | 100.0 |

**Source:** Field Survey Data, 2011

The adoption of new crops was not done in arbitrary, rather it was due to a number of reasons including environmental stress and other socio-economic factors. The impacts of CC&V seem to be the major cause of this adoption. However, there are other reasons as highlighted in Table 5.

**Table 5: Reasons for Adopting New Crops**

| Reason for adopting | N=80 |
|---|---|
| Business | 6.1 |
| Diseases | 13.8 |
| Drought | 65.0 |
| Flood | 7.5 |
| Market | 1.3 |
| Poor soil | 6.3 |
| Total | 100.0 |

**Source:** Field Survey Data, 2011

Apart from abandoning and adopting new crops, some farmers have shifted to lowland areas which maintain water even during the dry season. The aim of this shift is to maintain the same crop they used to produce before (Lobell, D. & Field, C. 2007). In lowland areas rice production flourishes well. However, the shift to lowland areas is limited by small farm land found in those lowland areas.

***The Implications of Crop Yields on Food Security***

**" The Implications at National Level"**

Until recently, most assessments of the impact of climate change on the food and agriculture sectors have focused on the implications to the production and global supply of food, with less consideration of other components of the food chain (FAO, 2008). Poor yields in most cases lead to food shortage hence bring about food insecurity.

Under this aspect, Self Sufficient Ratio (SSR) is considered to estimate deficit of food in the society. It is calculated as follows:

SSR = Production/Requirement X 100%
Example, The Production of food at national level in the year 2002/2003 was 7,373,020 tones while the Requirement was 8,142,882tones.
Thus, SSR = 7,373,020/8,142,882 X 100%
Therefore, SSR = 0.9 X 100%
Hence, SSR = 90%
Basing on the results above, 90% was the Self Sufficient Ratio at the national level in the year 2002/2003 while 10% was the deficit of food required. Hence, 10% indicates the level of food insecurity in the country at that year (2003). Hereunder are the results of SSR from 2000/01 to 2010/2011 in few regions.

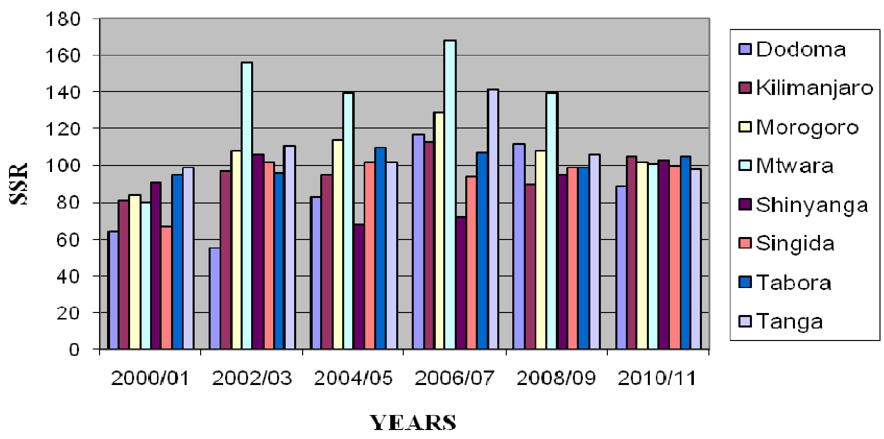


**Figure 13:** SSR from 2000/01 to 2010/2011 Based on the Few Selected Regions
**Source:** URT, 2010
With reference to Figure 13, the SSR of Tanzania at national level shows that the average SSR is 101% which means that the food required by the entire population has been produced. Hence, there is no food deficit at the national level. This is not necessarily to be true at regional or local level. There might be food security at national level while a number of regions are facing the problem of food insecurity. At regional level, there are some regions with deficit food requirement as their SSR is less than 100%. Examples of these regions includes; Singida, Shinyanga, Dodoma and Kilimanjaro. This happens while at national level there is food security. Furthermore, the same case can happen at District level. The District can experience food shortage while at national level there is surplus food. Poor food distribution, unorganized market and resilience to climate change and variability (CC&V) impacts are some of the reasons for this food inequality within the same region.

**"The Implications at Local Level (Makuyu and MvomeroVillages)"**

As applied at the national level, Self Sufficient Ratio (SSR) can also serve as the most important determinant factor for food surplus and deficit at local level. Thus, hereunder is a calculation of SSR based on Mvomero and Makuyu villages.
SSRof the area = Production/Requirement X 100%
Data given:

(i) Production in the two villages according to household survey (2011) = 913 bags of 100kg (91300 kg) of maize, sorghum and rice per annum.
(ii) The annual requirement is 113008.35kg of cereal crops. This figure has been obtained through the following procedure;
-The number of adult people in the two villages is 476.
-The daily requirement of starch per adult person is 0.65kg.

Therefore, the daily starch requirement of the total population in the area:
=Total Population X 0.65kg
Hence, 476 X 0.65= 309.4kg
Consequently, 309.4kg being the daily food (starch) requirement, then the annual food (starch) requirement for the total population in the study area (Mvomero and Makuyu villages) = 309.4kg X 365.25=113008.35kg.
Since SSR = Production/Requirement X 100%
As a result,

SSR = (91300 kg/113008.35kg) X 100% = 80%

Therefore, the implication of 80% as the SSR in the study area is that there is an average shortage of 20% of food in the study area. Thus, out of 365.25 days, there are about 70 days in which people experience food insecurity and starve for that.

As a way forward, short and long term measures need to be taken immediately in order to reduce this problem. In addition, the people in the study area have undertaken some adaptation measures. About 75% of the total respondents reported that they have reduced the number of meals from three to two or one. This means that the majority are living under critical condition of starvation. Thus, the problem of food insecurity in the study area has been mainly caused by the the impacts of climate change and variability as reduced rainfall and increased temperature have adversely affected crop production which subsequently leads to crop failure.

**5.** Conclusion

Analysis from quantitative and qualitative data provides evidence that the impacts of climate change and variability have adverse affects on crop production in the study area. The results confirm that there is a correlation between the variability trends in rainfall and temperature, and that of crop production as shown in Figure 6, 9 and 11 respectively. Rainfall is fluctuating at a decreasing trend while temperature is fluctuating at an increasing trend. The two variables determine the production trends of crops.

The findings shows that the decrease in rainfall (Figure 6) and increase in temperature (Figure 9) lead to the decrease in crop production (Figure 11). These trends are supported by the results from field survey through PRAs in which 71.3% of the respondents reported that rainfall is decreasing and 97.5% said that temperature is increasing. Therefore, decreasing rainfall and increasing temperature are affecting crop production negatively in the study area.

***Recommended Adaptation***

Based on the findings and conclusion above, the researcher recommends that there is a need for people to adopt relevant adaptation measures and coping mechanisms in order to reduce vulnerability of their livelihoods so as to improve food security in the study area. These adaptation measures aim to improve the already adopted mechanisms and establish the new ones (Orindi, V. & Murray, A. 2005). However, adaptation measures may differ from one place to another depending on the level of socio-economic vulnerability and entitlement.

Therefore, some of the recommended adaptation measures and coping mechanisms which some of them were also recommended by (Agrawala, *et al.* (2003) include:

- Increased irrigation and modification of irrigation techniques, including amount, timing or technology (e.g. drip irrigation systems) in areas with severe drought. This will sustain the production of rice which demands more water.
- Early seed crop planting especially paddy in lowland areas in order to have a good timing on the fluctuating and shrinking growing season.
- Adopting and planting drought resistant crops such as sorghum. Although the crop already exists in the study area, but it is not well adopted and cultivated on large scale.
- Increasing awareness on how to reduce the impacts of climate change and variability such as maximization of positive opportunities like adopting the crop which seem to be favored in stressed condition. Also, reduction of negative impacts by increasing adaptive capacity for the purpose of reducing the vulnerability of crops.
- Extension officers should provide frequent extension services to farmers.
- Adoption of water-efficient technologies to harvest water, conserve soil moisture (e.g. crop residue retention, zero-tillage), and reduce siltation and saltwater intrusion.
- Modification of crop calendars, i.e., timing or location of cropping activities.
- Integration of the crop, livestock, forestry and fishery sectors at farm and catchment levels.
- Implementation of seasonal climate forecasting.
- Settlement of disputes between crop cultivators and livestock keepers. Each of the two groups of land users should have its own land. This will reduce land degradation and crop destruction caused by the movement of livestock in farms.

Therefore, the above named adaptation measures can be adopted from the local to national level and even beyond that depending on the nature of agro-ecological zones, level of socio-economic development, magnitude of vulnerability and resource endowment. In addition these adaptation measures may involve several stakeholders such as the community, researchers, extension officers and policy makers.

 

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## Biography of the author

Msafiri Mkonda was born in Iringa Rural District, Tanzania on 15th of June, 1981. He graduated a Master Degree in Natural Resources Assessment and Management, at the University of Dar Es Salaam, in Dar Es Salaam, Tanzania in 2012. Before that, he had a bachelor degree in Education (Arts) with specialization in Geography obtained from the same university in 2007. His area of publication is agriculture, climate change, food security and environment. His is more interested in Human Geography where the vulnerability of the majority communities needs to be addressed. He has been lecturing geography courses at Sokoine University of Agriculture, Tanzania from 2008.