ISSN No:-2456-2165

Seasonal Rainfall and Maize Yield Variability Patterns in Baringo South Sub-County, Kenya

Ondiko H. Jackob1, Maranga K. Elias2 and Eshiamwata W. George3
1. Ondiko H. Jackob (Geography) Mount Kenya University
P.O.BOX 342-01000, THIKA – KENYA
2. Prof. Maranga K. Elias(Boundary layer climatology/Ecosystems ecology) Egerton University
P.O Box 536-20115, EGERTON, NJORO, KENYA
3. Dr. Eshiamwata W. George (GIS/Conservation biology) Egerton University
P.O Box 536-20115,EGERTON, NJORO, KENYA

Abstract:- Climate variability is a major constraint in the attainment of food security among households in water-stressed environments. Communities in water-stressed environments have increased efforts to enhance agricultural productivity. However, the spasmodic nature of rainfall particularly in dry-land areas compounded by climate change and its effects on rainfall amounts and frequency has implications on food security. The central focus of this study was to assess the seasonal rainfall and maize yield variability patterns in Baringo South Sub-County. Empirical rainfall and maize yield data for the period 1996-2016,was obtained and analysed to determine the pattern of correspondence between seasonality and yield production function. Baringo South Sub-County is an Arid and Semi-Arid Land (ASAL), a water-stressed environment and was a suitable site for this study. A case study research design was adopted for this study. Secondary data on maize yield (bags/ hectare) was collected from Baringo County Agriculture Office (Kabarnet) and Baringo South Sub-County Agriculture Office (Marigat). Rainfall data was obtained from National Irrigation Board (NIB), Kenya Agriculture and Livestock Research Organization (KALRO) and Snake Farm weather stations (Marigat). The results of this study indicated that seasonal rainfall and maize yields have a corresponding pattern in fluctuation over the years of study. Conclusively, amount of seasonal rainfall affects seasonal maize yield. Statistical Correlation for mean seasonal rainfall and seasonal maize yield was significant where R2 value of 0.375, indicated that the rainfall variability explained 37.5 % of the maize yield variation. The results indicated that 86.6%of the small-scale farmers recorded change in rainfall occurrence; indicating that climate change was experienced by majority of the small-scale farmers. The majority of the small-scale farmers (41.9%) produced between 6.0-10.0 bags of maize with the mean for maize production in bags per hectare calculated as 8.05. The low production of maize in bags per hectare in the ASAL indicated that rainfall variability affected its production marginally. This study provided information on rainfall variability and its impact on crop production, which can be used by the Government to improve maize crop production by the local communities.

***Keywords**:- Climate Change, Climate Vulnerability, Drought, Food Security, Water Stress.*

I. INTRODUCTION

Food insecurity is a major global problem despite the effort made to improve agricultural production (Herrero et al., 2010). According to FAO (2008) 805 million people were undernourished; 161 million children were stunted in growth, 51 million wasted and 2 billion people suffered from micronutrient deficiencies globally. Challenges to food security included increasing global population, changing diets, climate change and severe weather events. Food demand was expected to increase two to threefold by 2050 (FAO, 2008). Food insecurity remains a major challenge globally despite the efforts made to improve agronomic productivity.

Central to food production, is rainfall variability. According to FAO (2008), agriculture was the most significant user of water for crop growth, and development. A study conducted in Mozambique by Oseni and Masarirambi(2011) indicated a decline in rain-fed maize production in some parts of the world. On this basis, climate change-proof and drought-resistant crops were recommended.Global annualmaize totalling 600million tonnes is produced on 136 million hectares. In the tropics, maize is produced on 61.5 million hectares with an annual production of 111 million tonnes per year. In the tropical regions, the average maize yield per hectare is 1.8 tonnes per hectare, while globally the production is at 4.2 tonnes per hectare (CIMMYT, 1995).

The combined global maize yield from both irrigation farming and rain-fed agriculture was found to increase at a rate of 1.3% to 1.4% per year. The global annual white maize output was 60 to 70 million tonnes representing 12%-13% of global annual output of maize, of which 90% of the white maize was produced by the developing countries which depended on it as a staple food, (FAO 2008).A large population of the inhabitants of Africa depended on maize as a primary source of food, whose global demand has superseded the supply of the produce (Akanbiet al., 2004). Kurukulasuriyaet al. (2008) indicated that the causes of the annual global food shortage included: desertification, drought, climate change, and rainfall variability.

The approximate global population affected by water-stress due to global rainfall variability was projected to reach 3 billion people by 2030globally with about 75 million to 250 million being in Africa (FAO, 2007).

According to Cakir (2004), the Horn of Africa; East and North-Eastern Africa, experienced recurrent periodic droughts leading to aridity, famine and malnutrition, thereby, creating the need to develop drought resistant crop seeds for such poor conditions. Oseni and Masarirambi(2011) argued that the risk associated with climate variability on maize crop yield depended mainly on the growth stage of the crop; when weather hazards such as meteorological drought occurred. This point of view was also supported by Cakir (2004) whose study indicated that the scarcity of water during the growth and development phases negatively affected crop yield.

Maize water requirement for consumptive use, for germination, growth, and development for the maize plant and particularly rainfall water was found to be less than 500 mm in the tropical lowlands and less than 350 mm in the highlands (McCann, 2005). According to Ammaniet al. (2012), maize production within a season needed a mean rainfall of between 500 mm to 800mm. A study conducted by Abdul et al. (2007), using FAO CROPWAT model on loamy, sandy soils in Kuwait, based on agro-ecological data of 43 years, found out that maize crop water requirements vary from 210 mm for a 90-day crop to 273 mm for a 110-day crop. Higher amounts of water beyond the amounts indicated for the two stages above reduced yield. Tekwa and Bwade (2012) found that the consumptive use of water by maize may range from 4.35 mm/day during the long rainfall season to 3.10mm/day during the short rainfall season.

According to Herrero et al. (2010), agriculture was important to the economy of Kenya and contributed approximately 26% to the Gross Domestic Product (GDP) and employed approximately 70% of the rural population. The importance of maize to Developing Countries' economy was also elaborated by Msafiri (2014) whose study indicated that maize was a major staple food crop in many African countries, though the demand outstripped the supply of the produce. According to Nyangito and Nyameino (2002), Kenya regularly experienced shortfalls in maize production with a mean of 2.4 million tonnes during early 2000, translating to 79 bags per person against an estimated maize consumption requirement of 103 bags per person. Approximately 90% of the population depended on maize for direct consumption (Nyangito and Nyameino, 2002). Maize for subsistence and commercial purposes was grown on approximately 1.4 million hectares by large-scale farmers at 25% and small-scale farmers estimated at 75% of the entire cultivated maize land (GOK, 2005).

According to Msafiri (2014), food insecurity was experienced in ASALs, hot climatic regions and regions with degraded farm-lands, increasing the climate vulnerability of small-scale farmers. IPCC (2007) also indicated that agro-ecological zones of the world were possibly shifting as a result of the climate change, desertification and drought occurrence consequently impacting agriculture. According to Mwaura and Okoboi (2013) and Omolo etal. (2010), seasonal rainfall variability was a key parameter in determining maize crop yield, thus rainfall was considered as the main source of water for both rain-fed agriculture and irrigation.

The importance of rainfall variability in the determination of maize yield was also reported by Herreroet al. (2010) and Ketiemetal. (2013) whose studies indicated that the ASALs in Kenya comprised 80% of the total land surface; where rain-fed agriculture was widely practised and that agriculture was a vital pillar of economic development of all nations. Mogakaet al. (2009) found out that variability of rainfall in Kenya exhibited a biannual occurrence pattern followed by famine at every drought episode. Baringo South Sub-County, an ASAL, experienced a modified tropical climate of the highlands with high frequency of droughts and rainfall variability. The recurrent droughts in the region, consequently led to water-stress, degradation of farm-lands, ecosystem destruction and increased soil acidity and salinity. These conditions were not favourable to maize crop production, Oseni and Masarirambi(2011).

Tekwa and Bwade (2012) also indicated that the vegetative stage of maize crop growth (3rd leaf to 9th leaf) was critical and the yields at this stage increased with the increase in rainfall during the period from 200-300 mm at uniform intervals. The study indicated that the most water sensitive stage was the reproductive stage (tasseling/ silking or grain formation) stage where rainfall amount ranging between 200-250 mm had a significant yield enhancing effect. The frequent occurrence and magnitude of rainfall variability experienced in Baringo South Sub-County as a result of climate change events such as drought, led to an extended period when Baringo South Sub-County received insufficient water supply (McCann, 2050).

Even though harsh climatic conditions were experienced in BaringoSouth, Sub-County; the small-scale maize farmers were resilient and persistently cultivated maize thereby harvesting each year for domestic consumption. Adoption of new farming technologies and appropriate technology towards agricultural production was recorded in some of these areas especially the ASALs that experience spasmodic, seasonal rainfall that was harvested for irrigation farming (Cakir, 2004). The necessity to cope with rainfall variability is attributed to the facts of the findings of a study conducted in Egypt by Samihaet al. (2014), which indicated that water requirement for maize production is expected to be 10-15% by 2040; effectively leading to a decline in area under cultivation.

A recent study conducted by MOA (2013) indicated an unreliable pattern of rainfall in Baringo South Sub-County, which experienced the long rainfall season, from March to August with minimal and sporadic rainfall, and a prolonged dry season from September to January. According to FAO(2012), rainfall effectiveness is low in the ASALs. Shiferawet al. (2011)reported that a decline in acreage of land under maize production globally was recorded due to desertification and climate change-related events such as drought. Africa recorded a decline of 43% in acreage under maize. Maize was identified as the leading staple food in Kenya (GOK, 2005).

Even though a lot of effort was made toward increasing maize production, there was still a huge deficit in supply of the crop to feed the world population particularly the populations in the developing world. The historical annual maize yield was notably marginal at 1% or less and though this percentage may have reached 1.7% tonnes per hectare (Tribe, 1994). The seasonal and annual variability nature of climate-related phenomena such as rainfall, require long time series data. This study, therefore, covered data of a long period of 20 years as climate-related studies were advisably conducted over long periods due to the gradual; temporal and spatial change in climatic conditions.

II. RESEARCH METHODOLOGY

The case study research design was adopted for this study where data of mean seasonal rainfall and maize yield in bags per hectare was collected for the period 1996 to 2016. The 20 year period was used since climate change studies are advisably done considering a long period of time. The seasonal rainfall data was collected from the National Irrigation Board (NIB), Snake Farm and KALRO Meteorological Stations in Marigat. The maize yield data was obtained from Baringo South Sub-County (Marigat) and Ministry of Agriculture (MOA) records(Kabarnet). The maize yield was notably recorded from the maize produce during the rainfall season of March to August in Baringo South Sub-County. The maize yield was analysed based on total bags of maize produced per hectare for each year from the Sub-County. A regression function explaining the yield variation associated with rainfall was derived from secondary data of mean seasonal rainfall and maize yield.

III. RESULTS AND DISCUSSION

A. Seasonal Rainfall Pattern

Evidence from this study showed that seasonal rainfall fluctuated over the period of study (Figure 1).These substantial fluctuations implied that the study area was affected by climate change. These findings were in agreement with studies conducted in Kenya and Uganda by Kandji (2006), Mwaura and Okoboi (2013) which indicated that a fluctuating pattern of rainfall was recorded in the last two decades and was attributed to climate change. Statistical tests including Regression analysis with $p \leq 0.05$ were carried out. Statistical Correlation for maize yield and climate variability was significant where R2 value of 0.375, indicated that the rainfall variability explained 37.5 % of the maize yield variation.

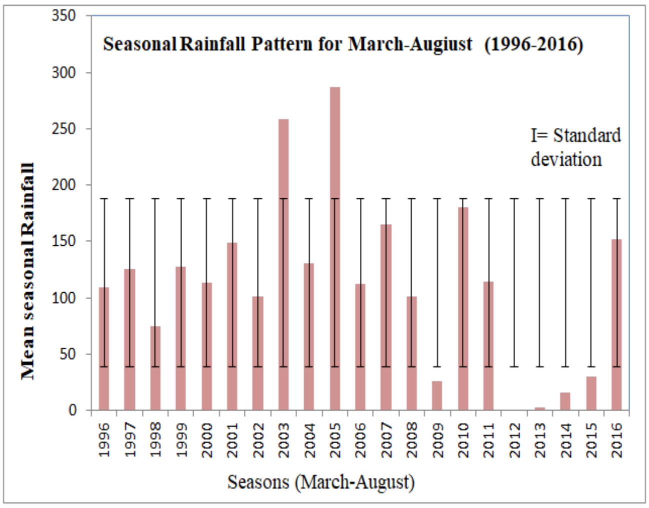

Fig 1:- Seasonal Rainfall Pattern for March to August (1996-2016)

B. Change in Number of Rainfall Days

The majority of the small-scale farmers (75.4%) recorded decrease in rainfall days (Figure 2). These findings were in agreement with results of studies conducted in Kenya and Uganda by Kandji (2006), Mwaura and Okoboi (2013) respectively, which indicated that there was a change in the number of rainfall days recorded in the last two decades and was attributed to climate change.

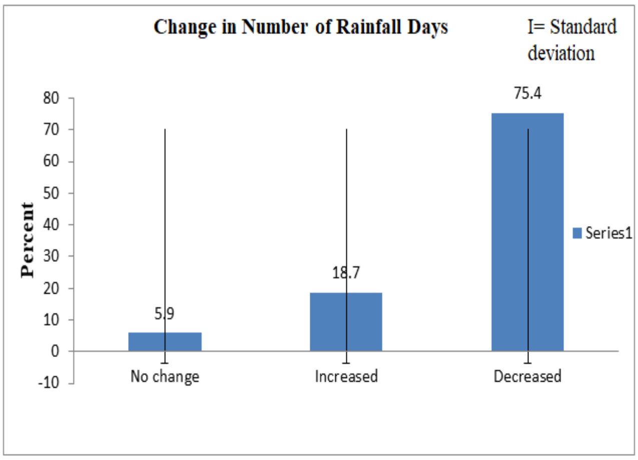

Fig 2:- Change in Number of Rainfall Days

C. Change in Time of Occurrence of Rainfall

A substantial proportion of small-scale farmers (86.6%) recorded change in rainfall occurrence (Figure 3).The change in occurrence of rainfall was attributed to climate change. These findings were in agreement with results of studies conducted in Nigeria and Kenya by Ammaniet al. (2012) and Kandji (2006) respectively, which indicated that a change in occurrence of rainfall was recorded in these countries.

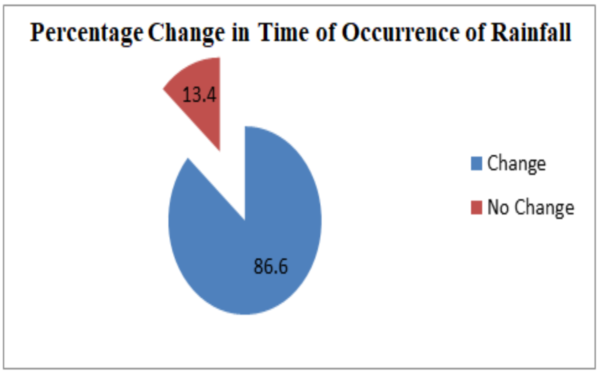

Fig 3:- percentage change in Time of Occurrence of Rainfall

D. Type of Change in Time of Occurrence of Rainfall

The majority of the small-scale farmers (66.4%) recorded late occurrence of rainfall, while 33.6%of the small-scale farmers recorded early occurrence of rainfall (Figure 4). The change in occurrence of rainfall may be attributed to climate change. The difference in observations in a change in rainfall days was attributed to the period of farming, experience in farming, level of education, recording of farming activities and interest in farming by the small-scale farmers. These findings were in agreement with the results of a study conducted in Swaziland by Oseni and Masarirambi (2011).

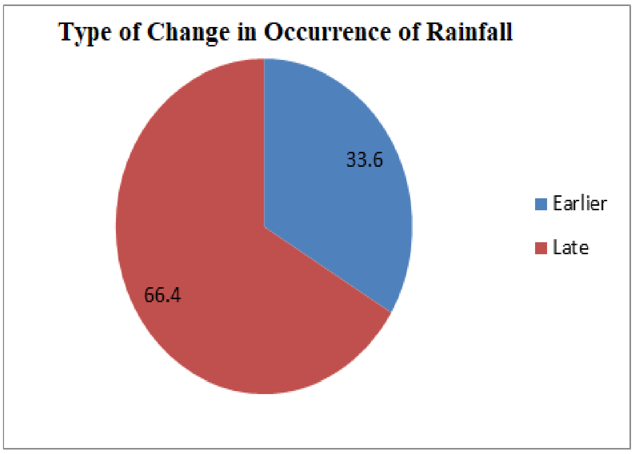

Fig 4: Type of Change in Occurrence of Rainfall

E. Maize Produce per Hectare in 2016

Evidently, close to 50%of the small-scale farmers produced between 6.0-10.0 bags of maize, followed by 24.6%who produced between 0.0-5.0 bags of maize, 14.2% produced between 16.0-20.0 bags of maize 8.2% produced between 11.0-15.0 bags of maize and 11.1% produced above 21.0 bags of maize respectively(Figure 5). These findings implied that; with appropriate coping strategies, maize yield can increase in the ASALs despite rainfall variability. These findings were in agreement with studies conducted in Kenya by MOA (2011) and MOA (2013) which indicated that the small-scale maize production under rain-fed agriculture produced approximately 8 bags per hectare. Even though the amount of maize produced is commendable, studies conducted in by FAO (2012) indicated that the ASALs have the potential to increase maize yield in bags per hectare when quality maize seeds are used. This study also concurs with a study conducted in the United Kingdom by Roser and Richie (2014) which indicated that maize production in the wet and high altitude regions can potentially produce between 1.3 to 8.3 tonnes per hectare under rain-fed conditions. There is need to improve on rainfall variability coping strategies and mitigate climate change in order to improve maize yield per hectare.

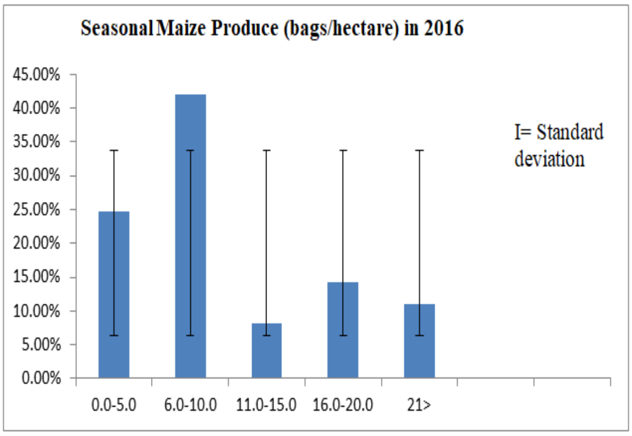

Fig 5:- Seasonal Maize Produce (bags/ hectare) in 2016

F. Maize Yield for the Period 1996-2016

A fluctuating pattern in maize yield in the 20 years period of study is authenticated. It was found out that maize yield for 2000, 2003, 2005 and 2015 was notably high whereas maize yield for 1997, 1999, 2009 and 2014 was notably low (Figure 6). The variations in maize yield at different maize production seasons occurred due to climate change. High maize yield was linked to high rainfall and vice versa. These findings implied that maize yield can potentially increase in the ASALs. The findings of this study concurred with findings of a study conducted in countries in the Sub-Sahara by Bremner(2012) which indicated that Africa faced the challenge of food insecurity as a result of rainfall variability and its impact on crop production.

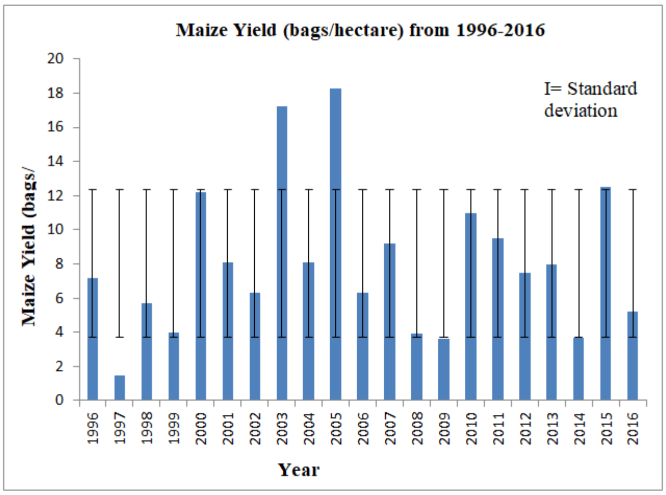

Fig 6:- Maize Yield (bags/ hectare) from 1996-2016

G. Descriptive Statistics for Maize Yield (Bags/Hectare)

The results of this study indicated that the mean for maize production in bags per hectare was 8.05 (Table 1). This finding is in agreement with studies conducted in Kenya by MOA (2014) and MOA (2016) which indicated that the small-scale maize production under rain-fed agriculture in ASALs produced approximately 8 bags per hectare.

Statistic	Value
Mean	8.05
Median	7.50
Standard Deviation	4.32
Minimum	1.50
Maximum	18.30
N=21	

Table 1:- Descriptive Statistic for Maize Yield (Bags/ Hectare)

H. Mean Seasonal Rainfall and Maize Yield

The results of this study indicated that there was a similarity in pattern of fluctuation of seasonal rainfall and maize yield (Figure 7). This implied that the amount of seasonal rainfall affected maize production during a growing season. The results of this study concurred with a study conducted by FAO (2012) which in indicated that rainfall variability affects crop production, creating the need to cope with water-stress.

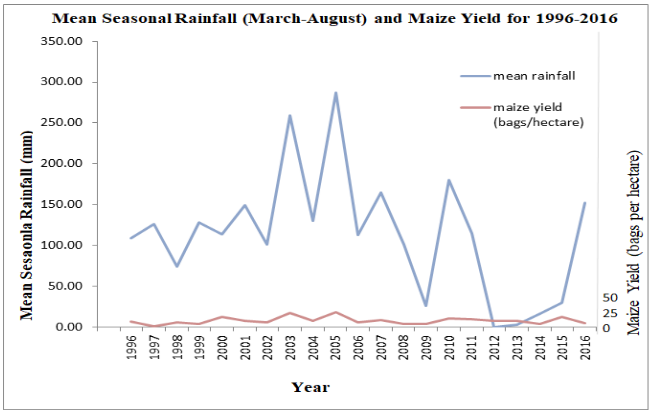

Figure 7: Mean seasonal rainfall (March-August) and maize yield for 1996-2016.

IV. CONCLUSIONS

Seasonal rainfall and maize yields have a corresponding pattern in fluctuation over the years of study. Increase in the amount of seasonal rainfall is associated with a corresponding increase in maize yield and vice versa. Conclusively, amount of seasonal rainfall affects maize yield. Statistical Correlation for mean seasonal rainfall and seasonal maize yield was significant where R2 value of 0.375, indicated that the rainfall variability explained 37.5 % of the maize yield variation. The implication is that by synchronization of agricultural calendar of maize production activities with the rainfall cycle in terms of rainfall onsets and planting dates, productivity could be enhanced. The results indicated that majority of the small-scale farmers(86.6%)recorded change in time of rainfall occurrence. Conclusively, rainfall variability was attributed to climate change and the consequent relative maize yield production. The majority of the small-scale farmers (41.9%) produced between 6.0-10.0 bags of maize with the mean for maize production in bags per hectare calculated as 8.05. Conclusively, maize production in bags per hectare was low in the ASALsand was attributed to climate change. The implication is that coping with rainfall variability will potentially increase crop yield.

ACKNOWLEDGEMENT

I gratefully acknowledge the Management of Mount Kenya University for providing opportunity to the principal author for pursuance of a Master of Arts (MA) degree in Geography at the Institution. I am indebted to my supervisors; Prof. Elias K. Maranga and Dr. George Eshiamwata, co-authors of this paper for their scholarly commitment and professional assistance in my MAthesis research project. My appreciation also goes to Mr. Makau S. Lawrence;Baringo County Crops Development Officer, Mr. Mureithi James; Baringo South Sub-County Crops Officer for allowing the collection of secondary data of maize yield at the stations, Mr.Njau Peter (Mount Kenya University) for the review of the data, Mr. Boit Richard; the manager National Irrigation Board (NIB) Marigat, the management of Kenya Agriculture and Livestock Research Organization (KALRO) Marigat and Dr. Ochieng Richard (University of Eldoret) for enabling access to seasonal rainfall data of NIB, KALRO and Snake Farm respectively.

REFERENCES

[1]. Abdul, S. M. and Mazrooei S. A. (2007). Crop Water and Irrigation Water Requirements of Maize (Zea Mays L.) in the Entisols of Kuwait. https://www.researchgate.net/showpdf?booknr=736-29 Retrieved on 29th March 2017 fr

[2]. Akanbi, W., Olabode, O., Olaniyi, J. and Ojo, A. (2004).Introduction to Tropical crops. Published by Raflink Computer, Eleyele, Ibadan.

[3]. Ammani, A.A., Ja'afaru A.K., Aliyu J.A. and Arab A.I. (2012). Climate Change and Maize Production: Empirical Evidence from Kadena State, Nigeria, National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria-Nigeria. Journal of Agricultural Extension Vol. 16 (1), June 2012.

[4]. Bremner, J. (2012). Population and Food Security: Africa's Challenge. www.prb.org

[5]. Cakir, R. (2004). Effect of water-stress at different development stages on Vegetative, reproductive growth of corn.Field Research 89 (1), 1-6, Pakistan.

[6]. Centro International de Mejoramiento de Maiz y Trigo (1995). Modern Maize and Wheat Varieties; Vital to Sustainable Agriculture and Food Security.

CIMMYT, Int. https://www.cimmyt.org Retrieved on 14th July 2018.

[7]. Food and Agriculture Organization of the United Nations (FAO) (2008).Climate Change and Food Security, a framework document, FAO, Rome, Italy.

[8]. Food and Agricultural Organization of the United Nations (FAO) (2012). Coping with Water Scarcity. An action framework for agriculture and Food Security. http://www.zaragoza.es/ciudad/medioambiente/onu/en/detalleper_onu?id=450 Accessed on 8th September 2018.

[9]. Government of Kenya, (2005). "Economic Review of Agriculture" Ministry of Agriculture. Government Printers, Nairobi, Kenya

[10]. Herrero, M., Ringler, C., Steeg, J., Thornton, P., Zhu, T., Elizabeth, B., Omolo, A., Koo, J. and Notenbaert, A. (2010). Climate Variability and Climate Change: Impacts on Kenyan Agriculture, Washington D.C, (USA); International Maize Policy Research Institute. (ILRI)

[11]. Intergovernmental Panel on Climate Change, (2007) Climate Change 2007, Impacts, Copings and Vulnerability: Contribution of Working group II to the Fourth Assessment Report of IPCC, Cambridge, Cambridge University Press

[12]. Kandji, S.T. (2006). Rainfall variability in Kenya: Climatic, economic and Socio-political

[13]. Factors; Today New standpoints. Retrieved on 29th March 2017 from www.Globalagroforestry.org

[14]. Ketiem, P., Makenzi, P.K., Omondi, P., Maranga, E. and Wekesa, C. (2013). Trend analysis of Climate change and its impacts on crop productivity in the Lower Tana River Basin, Kenya.Oct. Journ.Env.Res. VOLUME 1 (4): 237-248

[15]. Lewandrowski, J. and Brazee, R. (1993)."Government Farm Programme and Climate Change: A First look", in J.M. Reilly and M. Anderson, eds., Economic Issues in Global Climate Change.Agriculture, Forestry, and Natural Resources. 24 (2): 132-147

[16]. Kurukulasuriya, P. and Mendelsohn, R. (2008). How will climate Change Shift agro-ecological zones and impact African agriculture? World Bank Policy Research Working paper 4717. World Bank, Washington D.C, USA.

[17]. McCann, C. J. (2005). Maize and Grace: Africa's encounter with a New World Crop, U.S.A.

[18]. Ministry of Agriculture, (2011).Annual Reports.Department of Agriculture and Livestock Development, Baringo District, Kenya.

[19]. Ministry of Agriculture, (2013).Annual Reports.Department of Agriculture and Livestock Development, Baringo District, Kenya.

[20]. Ministry of Agriculture, (2014).Annual Reports.Department of Agriculture and Livestock Development, Baringo South Sub-County, Baringo County, Kenya.

[21]. Ministry of Agriculture, (2016).Annual Reports.Department of Agriculture and Livestock Development, Baringo South Sub-County, Baringo County, Kenya.

[22]. Mogaka, H., Gichere, S., Davis, R., Hirji, R. (2009). Climate Variability and Water resources in Kenya; the economic cost of inadequate management. Washington D.C. Global Bank. MPRA paper No. 29750. Retrieved on 29th March 2017 from http://documentsglobalbank.org

[23]. Msafiri, M. (2014).Rainfall Variability and its association to the Trends of Crop Production in Mvomero District, Tanzania.Morogoro Tanzania, European Scientific Journal, July 2014. Edition Volume 10, No. 20.

[24]. Mwaura, F. M., Okoboi, G. (2013). Climate Variability and Crop yield in Uganda, Economic Policy Research Centre. (EPRC) Kampala, Uganda. March 18, 2014 https://dx.doi.org/10.5539/jsd.v7n2p159Retrieved on 29th March 2017

[25]. Nyangito, H.O. and Nyameino, D.M. (2002). "Maize Production and Marketing in Kenya" pdf.usaid.gov/pdf_docs/PNADN354.pdf

[26]. Omolo, A., Koo, J. and Notenbaert, A. (2010). Climate Variability and Climate Change: Impacts on Kenyan Agriculture, Washington D.C. (USA), International Maize Research Institute. (ILRI)

[27]. Oseni, T. and Masarirambi, M. (2011).Effect of Climate Change on Maize (Zea mays) Production and Food security in Swaziland.Luyengo, Swaziland, IDOSI Publications.

[28]. Roser, M. and Ritchie, H. (2014). Yield and Land use in Agriculture. Retrieved on 7th April 2018 from https://ourworldindata.org/yields-and-land-use-in-agriculture

[29]. Samiha, O., Noreldin, T. and Khaled, A. (2014). Water requirements for Wheat and Maize under Climate Change in North Nile Delta. http://dx.doi.org/10.5424/sjar/2015131-6412 Accessed on 8th September 2018.

[30]. Shiferaw, B., Prasanna, B., Hellin, J. and Banziger, M. (2011). Feeding a hungry world: Past Successes and future challenges to global food security in maize. Food security. 3: 307-327

[31]. Tekwa, I.J. and Bwade, E.K. (2012).Estimation of Water se of Rain-fed maize and groundnuts.www.akamaiuniversity.us/PJST13_527.pdf Retrieved on 29th March 2017

[32]. Tribe, D. (1994). Feeding and Greening the World. The Role of International Agricultural Research, CAB INTERNATIONAL, Wallington, UK.