Original Research Article

RAINFALL VARIABILITY AND VEGETABLE PRODUCTION IN BAMENDA III SUB-DIVISION, CAMEROON

ABSTRACT:

Climate variability has a direct bearing on agricultural production. The relationship between temperature and rainfall provides ideal conditions for the development of crops in rain-fed agricultural systems. This is patent in predominantly rain-fed vegetable production exposed to rainfall variability. As such, this study examines the impact of rainfall variability on vegetable production in Bamenda III Sub-Division. The data on rainfall was collected for 54 consecutive years (1963–2017) and analysed using Rainfall Anomaly Index to determine the Inter-Annual Rainfall Anomalies. This was to determine the extent of rainfall variability impacts on vegetable production. Results revealed a reliable but fluctuating periodical rainfall rates with highest positive and negative anomalies of +60mm and -55mm respectively. With a Standardized Precipitation Index of 0.41, there was evidence of an increasing trend in decadal rainfall and positive trend on conditions for vegetable cultivation. The high variability of rainfall is associated with a reduction in vegetable production output. Such rainfall variability plays a major role in vegetable production which is generally rain fed. The study posits that stakeholders' responsive adaptation options in for cropland management for vegetable production in the phase of rainfall variability are credible in reversing the increasing negative impact of rainfall variability in the context of climate

Keywords: ***Trends, Cropland, Vegetable cultivation, Seasonality, Farmers Adaptations***

1.INTRODUCTION

Climate variability has a direct bearing on agricultural production in the world [1]. Climatic variability refers to the climatic parameters of a region fluctuating from its long term mean, with some years having low average rainfall and temperature and others having high average rainfall (IPCC, 2007) cited in [2,3]. Globally, agro-climatic and socio-ecological system are interdependent as rural communities rely on climate-sensitive sectors for livelihoods that are based on agriculture [4]. This stems from the fact that the different agro-ecological zones and cropping systems are influenced by seasonality in the tropical climate. In the phase of global climate change and variability, sustainable cropland management for specific cropping systems are based on adaptation practices to extreme climatic events [5]. This is hinge on the principles of soil moisture quantity in periods of rainfall deficiency, soil fertility improvement and developing induced micro-climates for plant management and protection against climatic disasters [6].

Climate variability indicators manifested in the relationship between temperature and rainfall provides ideal conditions for the development of crops in rain-fed agricultural systems [7]. Rain-fed croplands account for more than 80% of global crop area and 60% of global food output, but are especially susceptible to the impacts of climate change [8]. Salient cropland management for vegetable production in the phase of rainfall variability cartels integrated knowledge-based approaches that embrace locally adaptable practices in optimising the productive proficiencies of market gardening lands in urban and per-urban areas [9]. Climate variability is one of the most significant determinants of year to year crop production variations both in high-yield and high technology agricultural areas [10]. With the shifting precipitation patterns and the rise of land and ocean surface temperatures by 0.65 to 1.06°C between 1880 and 2012 [11], there has been a decrease in crop yields [2]. This is more patent in Africa where agriculture contributes about 70% of the GDP [12]. By 2022, climate variability is predictable to reduce crop yields from rain-fed agriculture by up to 50% in Africa [1].

There has been the increasing development of cropland adaptation management technologies in many developing countries as decreased crop yields exacerbates food security vulnerabilities. This is evident in Sub-Saharan Africa where the pressure to cultivate marginal lands and unsustainable cropland management practices increased land degradation [13]. Climate variability in this region has further jeopardize food crops production and security with precipitation patterns are shifting as temperatures increases; reducing crop yields in tropical latitudes [14,15]. Rainfall availability and distribution vary widely throughout the seasons and affects soil moisture triggering agricultural drought with harmful effects like permanent wilting, stunted growth, reduced photosynthetic yield and possibly in extreme conditions may cause crop loss [16-17]. Extreme weather events such as droughts in some cropland ecological basins and floods in others are the main triggers of agrarian vulnerability. These have resulted to an established consensus that climate is changing and impacting more negatively than positively on agricultural-livelihood systems in most poor economies [18, 15, 19].

In Cameroon, agriculture directly employs about 80% of the work force and more than 90% on some rural areas of the Bamenda Highlands [20]. There has been an increase in temperature of 0.19^{0}C from 1930 to 1995 as compared with the 20^{th} Century warming rate of approximately 0.5^{0}C from 1900 to 1991. A predicted temperature increase of 1.8^{0}C by 2060 from the Cameroon data is far less than the global 3^{0}C for the year 2070 [21]. Analysis of trends in rainfall across the country during the 20^{th} Century indicated a net reduction of annual number of rainy days by seven days, while the total amount of annual rainfall dropped by 282 millimeters, equivalent to 43 millimeters per decade [22]. Crops are grown in the wetlands during the dry season and on dry lands during the rainy season with the North West and West Regions ranked as the highest vegetable producers in the country [23].

In Bamenda III Sub-Division, the crucial role of rainfall on cropland management dynamics for vegetable production is widely renowned. This is patent in predominantly rain-fed vegetable production exposed to rainfall variability. Dry spells and increasing temperatures tend to reduce germination resilience, multiply pest and diseases, accelerating the rate of evapotranspiration which further diminishes the availability of soil moisture leading to crop water stress [24]. Climate-agriculture studies in this area shows more focus on general food crop production impacts [21] neglecting the cropland management adaptations strategies on specific crops. This study is focused only on vegetable crops. This is therefore an existing research gap on this subject of rainfall variability and vegetable production in Bamenda III. This forms the originality of this study. This is based on the increasing quest from farmers developing adaptation cropland management strategies hinge on periodic soil moisture improvement to deter the impacts of rainfall variability on vegetable production. The rationale of this study is therefore to consider the cropland adaptation management strategies for improved vegetable production in the phase of rainfall variability in Bamenda III Sub-Division. This is founded in the context of annual and seasonal rainfall variability characteristics which affects cropland productivity. As such, the aim of this study is to examine the impact of rainfall variability on vegetable production. This is anchored on the premise that there are significant impacts of rainfall variability on vegetable production in Bamenda III Sub-Division.

2. MATERIALS AND METHODS

Bamenda III Sub-Division or Municipality is located between latitude 6'15 and 6'25N and Longitude 10'02 and 10'15E of Greenwich Meridian (Figure 1).

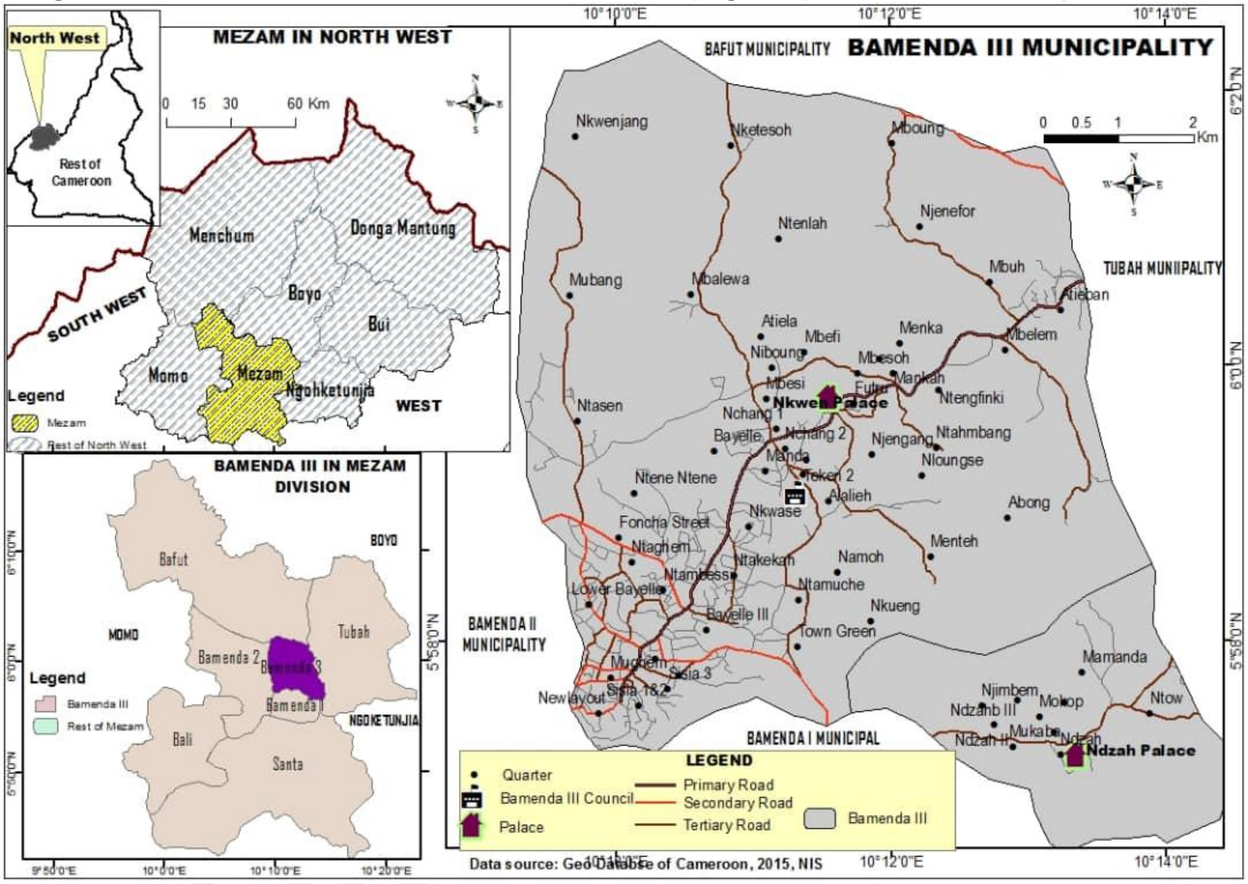

Figure 1. Location of Bamenda III Sub-Division in Mezam Division, North West Region, Cameroon

The Sub-Division is the main gateway to and from Boyo, Ngoketunja, Bui and Donga Mantung Divisions. It is bounded by Tubah Sub Division to the West, Bamenda I Sub-Division to the North, Bamenda II Sub-Division to the East and Bafut Sub Division to the South. It has a total surface area of $67.9km^2$ and a population estimated at 150,000 inhabitants [21]. The two autonomous villages of Nkwen and Ndzah make up the Bamenda III Sub-Division. There are 46 quarters in Nkwen and 9 in Ndzah village. The climate is a Guinea Savannah climate and the area reflects an agrarian landscape greatly influenced by seasonality (distinct rainy and dry season). The rainy season begins from March and extends to mid-October. The rainfall ranges between 1500-1800mm annually. The dry season begins from November and ends in February with temperatures hardly exceeds 24^0C [21]. This highland climatic zone constitutes a robust blend of micro cropland basin where climate change (long term) and variability (inter-annual, intra-annual) are major environmental indicators threatening cropland management practices and vegetable production systems.

In order to examine the relationship between rainfall variability and vegetable production, rainfall data was collected from the Bamenda meteorological station for a period of 54 years. Rainfall data was treated using Rainfall Anomaly Index (RAI) to determine the Inter-Annual Rainfall Anomalies. RAI, designed by [25] considers the rank of the precipitation values to calculate positive and negative precipitation anomalies. An increasing trend of RAI implies decreasing rainfall and vice versa. Extreme rainfall conditions that are not favourable for rain-fed tropical crop production in periods of extreme wetness are associated with flooding and extreme dry conditions are associated with severe soil moisture deficits which destroy croplands and lower crop yields. Positive anomalies have their values above the average and negative anomalies have their values below the average. The Standardised Precipitation Index was also used to determine the rainfall trends. Trend lines were fitted on the anomaly graphs to show changes in rainfall over the years. Cropland management and vegetable production data were collected for Huckleberry Tomatoes, Cabbages, Green Pepper, Eggplant, Bitter leaf and Okro. This data was gotten from the Sub-Divisional Delegation of Agricultural and Rural Development for Bamenda III Sub-Sub-Division and from the Agric Post in Ntene Ntene quarter. These datasets were treated in anomaly form to show positive and negative relationships with respect to variable rainfall conditions. This was complemented by 142 household questionnaires administered throughout the rainy and dry seasons in the urban, peri-urban and rural areas to capture farmers' perceptions of changes in cropland management practices and vegetable production output with respect rainfall changes.

3.RESULTS AND DISCUSSIONS

3.1. Rainfall variability from 1963-2017 in Bamenda Sub-Division

The incidence of rainfall variability in the Bamenda highlands is manifested in the Rainfall Anomaly Index used to assess climate variability, especially in the tropical agrarian [21]. The mean monthly rainfall within the Bamenda III in Bamenda Sub-Division indicates variations (Figure 2) from January (11mm) to December (11mm). Rainfall reaches the peak value in July (394mm) through August (387mm), then decreases to December (11mm).

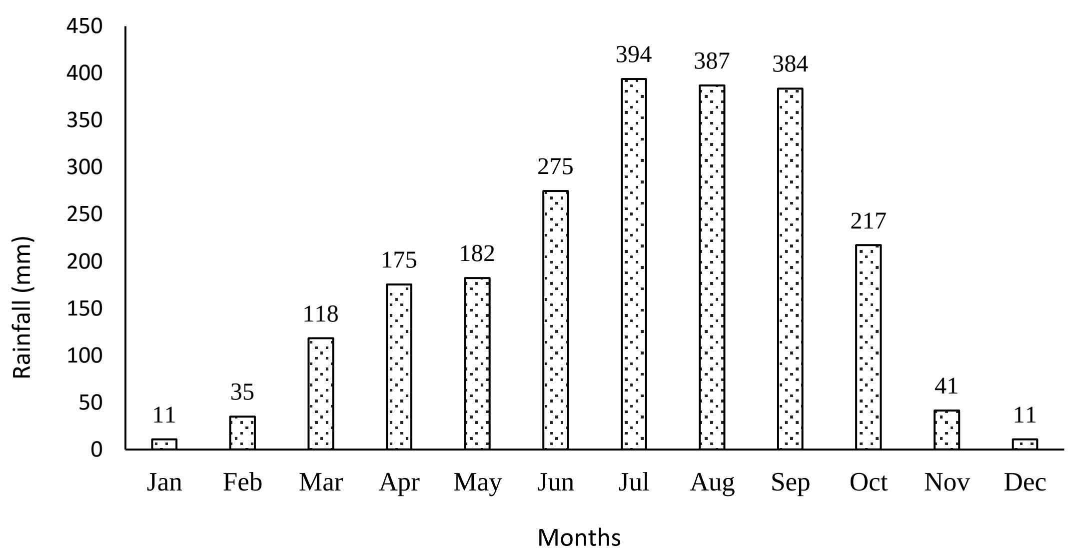

Figure 2: Mean monthly rainfall of Bamenda III Sub-Division

Data source: [26]

Rainfall variations directly determines the incidence of seasonality with dry (December to February) and rainy (March to November) seasons in the tropical climate [18]. Using inter-annual rainfall analysis, there has been a general fluctuation in the inter-annual rainfall recorded in Bamenda III Sub-Division ranging from high, medium to low rates of variants (Figure 3).

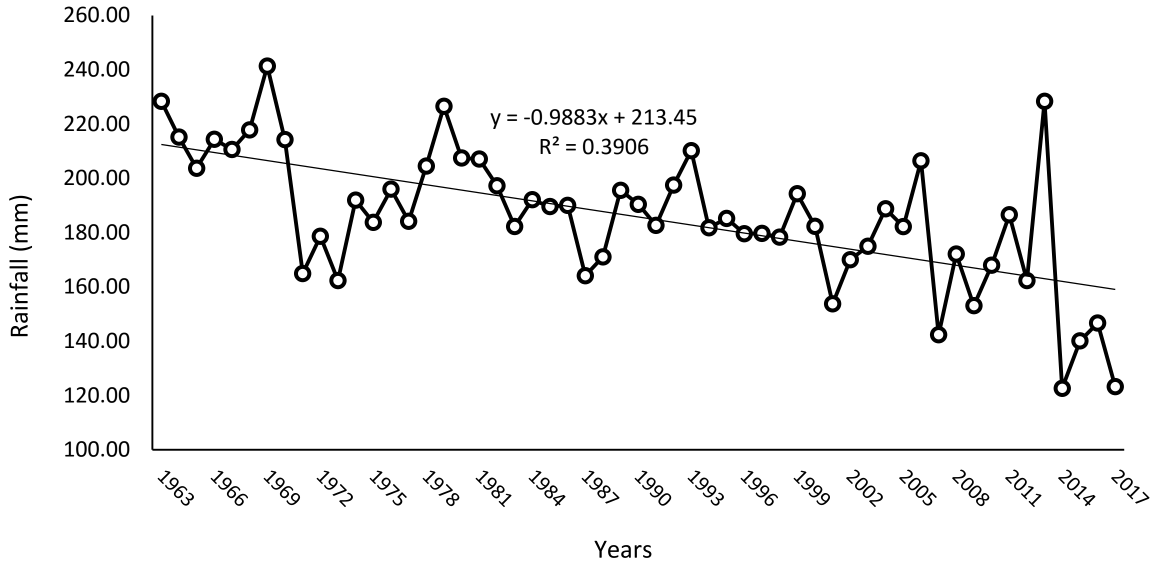

Figure 3: Inter-annual mean rainfall trends of Bamenda III from (1963-2017)

Data source: [26]

Years that recorded high fluctuations in inter-annual rainfall included: 1967,1978, 2005 and 2012. Years with low fluctuations in inter-annual rainfall includes 1970, 1972,1987, 2000, 2014 and 2017. Years with moderate fluctuations in inter-annual rainfall amounts were 1964, 1966,1980, 1981,1984-1986,1993-1999, 2008 and 2011.The inter-annual rainfall anomaly for 54years in the area shows a decreasing trends (Figure 4) from 1963 to 2017.

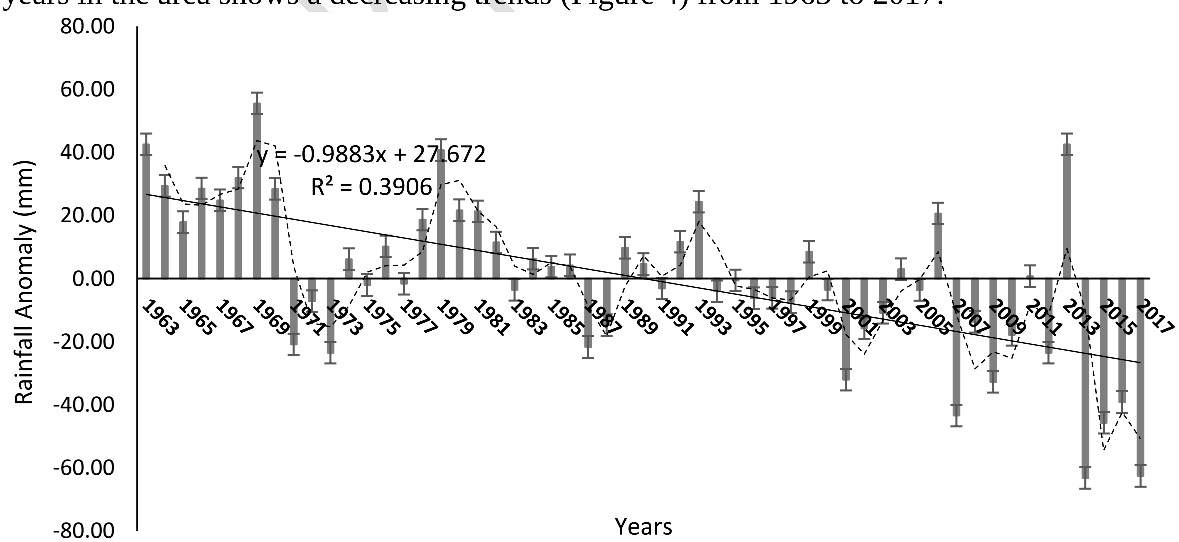

Figure 4: Inter-annual rainfall anomaly in Bamenda III Sub-Division

Data source: [26]

In 1972, the Inter Annual Rainfall Anomaly increased positively to 22mm and reduced after 1980 to 2017 with 2017 having a rainfall of -59mm. Using the SPI, there has been a general decrease in the trend from 1963-2017 (Figure 5).

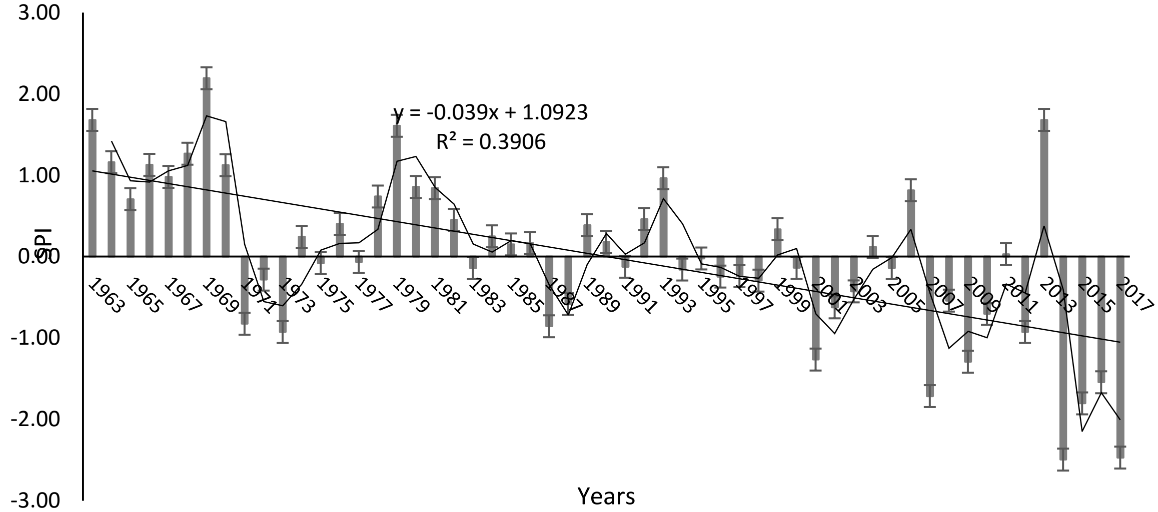

Figure 5: Inter-annual Standardized precipitation index (1963-2017)

Data source: [26]

Notable periods of low record rainfall were 1970-1973, 1975, 1977, 1983, 1987-1988, 1994, 1995-1998, 2001-2005, 2007-2012, and 2014-2017. The decadal SPI analysis from 1963 to 1972 shows 2 years of severely wet (1963 and 1969) with SPI of 1.8 and 2.19 respectively, 3years of moderately wet have been recorded which are 1964 (1.16), 1966 (1.13) and 1970 (1.12) and with 2 years of mildly wet that is 1965 (0.71) and 1967 with the SPI of (0.98) (Figure 6). The analysis of decadal SPI (Table 1) shows that 1963-1972 has decadal mean rainfall of 208.92 with SPI of 0.91 indicating a decreasing trend in decadal mean rainfall (mildly wet).

Table 1: Decadal mean rainfall and standardized precipitation index for Bamenda III (1963-2017)

Period	MR	SD	SPI	R^2	Trend	SPI Remarks
1963-1972	208.92	22.33	0.91	0.2927	Decrease	Mildly wet
1973-1982	196.1	17.33	0.41	0.4752	Increase	Mildly wet
1983-1992	185.52	17.33	-0.01	0.0286	Increase	Mild dryness
1993-2002	181.51	10.73	-0.17	0.4424	Decrease	Mild dryness
2003-2012	173.67	14.61	-4.78	0.1066	Decrease	Extreme dryness
2013-2017	152.19	43.85	-1.33	0.4507	Decrease	Severe dryness
Average	182.985	21.03	-0.83	0.2994	Increase	Mild dryness

MR: mean rainfall, SD: standard deviation

Source: Author's computation (2022)

The period between 1973-1982 has mean rainfall of 196.1mm with SPI of 0.41 showing an increasing trend in decadal rainfall from 1973-1982 (mildly wet). This positive trend shows favorable conditions for vegetable cultivation in dry land. The period 1983 to 1992 has mean rainfall of 185.52mm with SPI of -0.01 showing a decreasing trend in decadal rainfall from 1983- 1992 (mild dryness). This negative trend indicates unfavorable conditions for vegetable production in dry land. While the period from 1993-2002 shows the mean rainfall of 181.51mm with-0.17SPI showing a decreasing mild dryness. The mean rainfall and standard deviation from 2003-2012 was 173.67mm and 14.61 respectively. From 2013 to 2017 shows a decrease in severe dryness. The total average for SPI is -0.83 with an increasing trend towards mild dryness. This corroborates the analysis of the [17,4] indicating that positive trends in decadal rainfall creates favorable soil moisture conditions for plant growth.

3.2. Impact of rainfall variability on cropland for vegetable production

Statistical records of rainfall from 1963-2017 in Bamenda III Sub-Division shows that rainfall has been fluctuating but largely decreasing over time [21]. These periodic variations in rainfall has yielded negative weather and climatic impacts in vegetable production (Table 2).

Table 1: Negative climatic episodes from rainfall variability in Bamenda III Sub-Division

Impact	Frequency	Percentage	Months	Seasons
Meteorological drought	26	18.3	January -Febuary	Dry
Flooding	25	17.6	August to September	Rainy
Rising temperatures	64	45.1	December to March	Dry season
Seasonal variations	27	19.0	January-December	Rainy and dry seasons
Total	**142**	**100.0**	/	/

Source: Fieldwork (2022)

The consequences of rainfall variability in Bamenda III Sub-Division with rising temperatures recording (45.1%), seasonal variations (19.0%), drought (18.3%), and flooding (17.6%) respectively are perceived from the sampled population. Rising temperatures have caused a lot of damage to vegetable production. It has led to the predominance of pest like caterpillar and blight which affect vegetable production [27]. This pertains especially to the early growth of vegetable production thus, reducing the quality and quantity of vegetable production in Bamenda III municipality. Seasonal variation in terms of rainfall have affected vegetable production in that periods of the year recorded by high rainfall (July 394mm, August 387mm, September 384mm) tends to affect leafing, retard vegetable growth, affect ripening, and cause rotting of vegetable [2]. Low intensity of rainfall also affects vegetable production in that it leads to dryness especially in the months of November 11mm and February 35mm. This reduces the amount of soil moisture and makes the crops to dry up thus leading to reduction in vegetable production in terms of quantity and quality.

3.2.1. Impact of rainfall anomalies and vegetable production

Climate variability has significant impacts on agrarian systems, especially in developing countries, which are dominantly rain-fed crop production systems [20]. The seasonal variations in rainfall affects vegetable cultivation in spatio-temporal cultivation patterns. Between October to March more cultivation is seen in wetlands as heavy rains destroy most of the vegetables during the months with peak rainfall (Figure 2). This periodicity is contracted as most farmers in the area cultivate huckleberry, tomatoes, cabbages, eggplant around marshy areas and along river banks. This is due to the fact that heavy rains turn to destroy these vegetables while on the other hand some vegetables such as cabbages, bitter leaf, okongabong and pumpkin leaf are cultivated mostly during the months where rain fall is at its peak as heavy rainfall turns to favor the growth of these vegetables. The drop in vegetable production in heavy rainfall periods corresponds to farmers switching cropland management to the cultivation of other crops such as maize, beans, yams and Irish potatoes. These analysis deviates from [6] positing that heavy rainfall episodes in drought conditions provide ideal moisture conditions for crop development. This is explained in Bamenda III Sub-Division by the fact the climate does not suffer from drought and the cropland contains wetlands that constantly provide enough moisture conditions for vegetable crops.

The fluctuating inter-annual mean rainfall (Figure 3 and 4) implies that vegetable production has been changing in terms of quantities because there is a direct relationship between rainfall and vegetable production in this area. These fluctuations affect vegetable production due to the fact that certain vegetables are produced more than others since heavy rains favor the production of other types of vegetables like bitter leaf but do not favor others while less rainfall favors the cultivation of almost all vegetables especially tomatoes and spices. Also, the availability of land for vegetable production also reduces with heavy rains as land owners rent out land only within the period of less rains than the periods of heavy rains. This occurs because there is always crop production diversification during these periods. The decreasing SPI (Figure 5) trend shows a recurrence of dry episodes which negatively affect vegetable crops. This is seen in the wilting of crops as soil moisture and water resources negatively affects the human-environmental systems [20] in Bamenda III Sub-Division.

The increasing trend in decadal rainfall from 1973-1982 (mildly wet) with an SPI of 0.41 (Figure 5 and Table 1) shows a positive trend on favorable conditions for vegetable cultivation in dry lands. On the other hand, mean rainfall of 185.52mm with SPI of -0.01 from 1983 to 1992 was evidence of decreasing trend in decadal rainfall (mild dryness). This negative trend indicates unfavorable conditions for vegetable production in dry lands in this period as well as the period from 1993-2002 shows the mean rainfall of 181.51mm with-0.17 SPI showing but a decreasing mild dryness this also favors the cultivation of vegetables. Furthermore, the period between 2003 and 2012 indicated a decreasing trend towards extreme dryness with SPI of -4.78 which do not favor vegetable production. From 2013 to 2017 shows a decrease in SPI indicating severe dryness. The total average for SPI is 0.83 with an increasing trend towards mild dryness which favors the cultivation of vegetable in Bamenda III Sub-Division. One year of extreme wet (1969) with SPI of 2.19 can lead to floods which destroy vegetables. There are also 2years of mild dryness that is (-0.82) and 1972 (-0.28) which can reduce the soil moisture thus, affecting the quantity of vegetable production. During these periods as the case between 1971 and 1972 (Figure 5), most vegetable farmers tend to cultivate vegetable along the river banks and streams in order to have water for irrigation as echoed in the analysis of [9]. This reduction in SPI also leads to a reduction in the available land for vegetable cultivation as only few farmers have access to the land along the river banks and streams hence, a reduction in vegetable production.

3.2.2. Trends and rainfall variability driver in vegetable production

There is a positive increase in the production of each vegetable crop which changes from huckleberry (-12.7%), tomatoes (-16.2%), cabbages (16.9%), green pepper (57.2%), eggplant (-25.3%), bitter leaf (59.2%), okro (-19.8%), okongabong (59.2%) to pumpkin leaf (73.2%) (Figure 6).

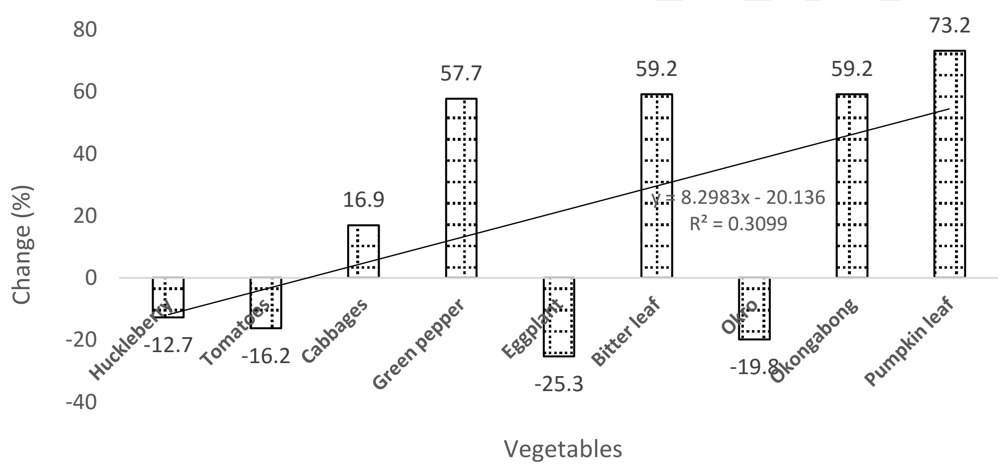

Figure 6: Vegetable production trends in Bamenda III Sub-Division

Source: Field Survey (2022); [27]

This positive trend is due to the fact that some vegetable types are new to the area, while others such as okongabong, pumpkin leaf, bitter leaf, serve dual function that is as food and medicine. Seasonal change brings about changes in output in vegetables. During the rainy season huckleberry production cycle indicates that 59.2% of the farmers produce less than 10 bags of huckleberry, 9.2% produce between 11-20bags, 20.4%produce between 21-30bags, 7% produce above 30bags of vegetable. For tomatoes 59.2% of the farmers produce less than 10 baskets during the rainy season (Table 3). This is due to the fact that excess rainfall does not favor the production of tomatoes meanwhile green pepper, eggplant, bitter leaf and okro are also produced during this season. The frequencies used are absolute frequencies.

Table 3: Seasonality and vegetable production output in the rainy season

Types of Vegetables	<10bags		11-20 bags		21-30 bags		30 bags+	
Rainy season								
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Huckleberry	84	59.2	13	9.2	29	20.4	10	7
Tomatoes	84	59.2	13	9.2	29	20.4	10	7
Cabbages	113	79.6	0	0	0	0	29	20.4
Green Pepper	113	79.6	0	0	0	0	29	20.4
Eggplant	113	79.6	0	0	0	0	29	20.4
Bitter leaf	113	79.6	0	0	0	0	29	20.4
Okro	113	79.6	0	0	0	0	29	20.4
Dry season								
Vegetables	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Huckleberry	29	20.4	0	0	113	79.6	0	0
Tomatoes	0	0	0	0	113	79.6	29	20.4
Cabbages	0	0	0	0	113	79.6	29	20.4
Green Pepper	0	0	0	0	113	79.6	29	20.4
Eggplant	0	0	29	20.4	57	40.1	0	0
Bitter leaf	0	0	57	40.1	85	59.8	0	0
Okro	0	0	29	20.4	113	79.6	0	0

Source: Fieldwork, (2022); [27]

Most of the farmers (79.6%) produce less than 10bags and 20.4% produces 30bags and above for each vegetable during the rainy season. This is because excess rainfalls affect them negatively thus reducing output [4]. The production of vegetables during the dry season fluctuate from one vegetable type to another in terms of the number of bags produce for the dry season period with an increasing trend. This is seen as many farmers are able to produce between 21-30bags of vegetable. This is accounted for by the fact that during the dry season vegetable is cultivated in the wetlands which many farmers are able to manage and so an increase in vegetable production. During the dry season, the climatic conditions favor the cultivation of vegetable like huckleberry, tomatoes, cabbages and green pepper. This is why between 40.1-79.6% of the farmers are able to produce between 21-30bags of vegetables for the dry season.

3.3. Cropland management adaptations strategies to rainfall variability

Multiple cropland adaptation management strategies by vegetable farmers are being used in order to optimize vegetable production in Bamenda III Sub-Division (Table 4).

Table 4: Cropland adaptation strategies for vegetable production

Adaptation strategies	Absolute Frequency	Absolute Percentage
Artificial water provision for crops	113	79.6
Using improved seeds	56	39.4
Soil conservation	68	47.9
Chemical fertilizers	31	21.8
Drought tolerant species	19	13.4

Daily watering of farms	69	48.6
Crop diversification	80	66.9
Zero-tillage	47	33.1
Diversification of cropping systems	26	18.3
Off-farm employment	12	8.5
Soliciting extension services	60	42.3

Source: Fieldwork (2022)

The most outstanding cropland adaptation strategy is artificial soil moisture provision for crops (79.6%). Farmers consider this measure as primordial due to the fact that crops only depend on moisture to grow. Alternative sources of moisture (Figure 7) are provided in the dry season when there is a negative balance in soil moisture.

Photo A: Canalisation of water into vegetable farm **Photo B: Watering using plastic bottles** **Photo C :The use of sprinklers in irrigation**

Figure 7: Farmers alternative moisture provision in dry periods in **Bamenda III Sub-Division**

Source Field Survey (2022)

These adaptation strategies have led to the increase in the vegetable production in the study area. These adaptation measures in cropland management have been increasing yields under stressful moisture conditions. Agricultural intensification has increased the financial and physical productivity patterns. This is seen in farmers' increasing yields, application of external inputs, irrigation and improved varieties of crops that farmers are already growing. Planting dates are being adjusted as farmers increasingly yield to local onset and offset rainfall predictions. The use of new crop cultivars with septic genetic traits are found most effective in reducing the adverse effects of dryness. This corroborates the findings of [21] that 70% of farmers in the Bamenda highlands use crop production response strategies by planting drought tolerant crops. Since most of the crops are cultivated all year round, majority of the farmers concentrate along rivers so as to have access to water for irrigation through, the use of buckets and through canals. Through this method, farmers divert a reasonable portion of water to their farms by blocking the main channel of the stream. This is typical amongst those who are cultivating vegetables like huckleberry, spices and cabbages. When the water is already connected to the farms either through pipes or canals some farmers used sprinklers to water their crops. Seasonal variations in the irrigation practices for vegetable crop production have made farms to depend on the daily watering of farms. These crops vary with respect to the periods they are cultivated as well as the periods in which they are watered (Table 5).

Table 5: Farm irrigation periods for vegetable production in Bamenda III Sub-Division

Crop type	**Period cultivated**	**Period watered**
Tomatoes	September-December	Morning and evening
Leafy spices	September to December	Morning and evening
Carrots	September to December	Morning and evening
Green beans	All year round	Morning and evening
Cucumber	All year round	Morning and evening
Leeks	All year round	Morning and evening
Huckleberry	All year round	Morning and evening
Water leaf	All year round	Morning and evening

Source: Field work (2022)

Watering of crops is done in the dry season and in exceptional cases in the rainy season when there is too much sun shine without rain. Crops like tomatoes, leafy spices, sweet pepper, tomatoes and carrots are cultivated from September to December. These crops need a lot of attention and they are well irrigated in the morning and in the evening with the use of watering cans and through canalization. Other crops are cultivated all year round and they are mostly watered in the dry season, which enables the soil to have enough moisture needed by the crops.

4. Conclusion and recommendations

A time series analysis showed that rainfall has been fluctuating in Bamenda III Sub-Division from 1963-2017. These seasonal rainfall peak in July (394mm), 3years of positive rainfall anomalies: 1969 (+60mm), 1979 (+40mm) and 2013 (+55mm) and 2014-2017 as periods of the highest negative anomalies (-55mm). The period from 2014 to 2017 were years of severe intermittent dryness and extreme soil moisture deficits. The increasing trend in decadal rainfall from 1973-1982 (mildly wet) with an SPI of 0.41 shows a positive trend on favorable conditions for vegetable cultivation in dry lands. On the other hand, mean rainfall of 185.52mm with SPI of -0.01 from 1983 to 1992 was evidence of decreasing trend in decadal rainfall (mild dryness). This negative trend indicates unfavorable conditions for vegetable production in dry lands in this period in Bamenda III Sub-Division. The high variability of rainfall correlated with a reduction in vegetable production output. Such rainfall variability plays a major role in vegetable production which is generally rain fed. This indicates a significant relationship between rainfall variation and vegetable production [28] as the frequency of extreme rainfall leading to flooding, pests and vegetable crops destruction and dry periods increase meteorological drought which reduces yields. The rainfall characteristics from the temporal variations of SPI show that rainfall is still reliable with drying trend in Bamenda III Sub-Division [24] with severe implications on crop production. These results are suggestive of the fact that the applicability of stakeholders' responsive adaptation options for cropland management for vegetable production through a blend of modern innovative practices and indigenous knowledge perception are plausible in reversing the increasing negative impact of rainfall variability in agriculture. This, in the context of climate change is a direct panacea to circumventing the stakes and challenges of cropland management for vegetable production exacerbated by rainfall variability.

DISCLAIMER: The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors

REFERENCES

1. Obwocha, E.B., Ramisch, J.J., Duguma, L., Orero, L. (2022). The Relationship between Climate Change, Variability, and Food Security: Understanding the Impacts and Building Resilient Food Systems in West Pokot County, Kenya. Sustainability 2022, 14, 765. https://doi.org/10.3390/ su14020765
2. Abu, A.H.Y., Salameh, A.A.M. and Fallah, R.Q. (2022). Precipitation Variability and Probabilities of Extreme Events in the Eastern Mediterranean Region (Latakia Governorate-Syria as a Case Study). Atmosphere 2022, 13, 131. https://doi.org/10.3390/ atmos13010131
3. Fonteh, M. L., Fonkou, T., & Lambi, M. C. (2016). Stakeholder Perception of Global Warming, Rainfall Variability and Sea Level Rise Hazard Perils in Three Coastal Districts of Douala-Cameroon". Journal of Environment and Earth Science, Vol. 6, No. 2, 2016.
4. FAO. (2021). The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point. Synthesis report 2021. Rome. Available at https://doi.org/10.4060/cb7654en. Consulted on 14/12/2021. 82p.
5. Tume, S.J.P., and Tanyanyiwa, V.I. (2018). Introduction to Climate Change Perception and Changing Agents in Africa and South Asia. Tume, S.J.P., & Tanyanyiwa, V.I., (Eds.) (2018). Climate Change Perception and Changing Agents in Africa and South Asia. Vernon Press, Wilmington, 1-33.
6. Food and Agriculture Organization of the United Nations-FAO, (2017). The state of food and agriculture climate change, agriculture and food security. FAO, Rome, 173.
7. Shahbandeh. M. (2017). Vegetable production worldwide. Management Practices under Tropical Conditions, International Journal of Vegetable Science, 20:3, 240-253, DOI: 10.1080/19315260.2013.800625
8. Regmi, R., Ma, Y., Ma, W., Baniya, B., Bashir, B. (2020). Interannual Variation of NDVI, Precipitation and Temperature during the Growing Season in Langtang National Park, Central Himalaya, Nepal. Appl. Ecol. Environ. Sci. 2020, 8, 218–228
9. Wentworth, J., Carver, L. and Donkersley, P. (2021). Sustainable land management: managing land for better environmental benefits. United Kingdom Parliament Repot on the land management. 37p. Available at www.parlianment.uk/global land. Consulted on 28/11/2021.
10. Kang, Y., Khan, S. and Xiaoyima. (2019). Climate change impacts on crop yield. Crop productivity and food security. A review progress in Natural Science.
11. Intergovernmental Panel on Climate Change-IPCC, (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D., Qin, G- K., Plattner, M., Tignor, S.K., Allen, J., Boschung, A., Nauels, Y., Xia, V., Bex, & P.M., Midgley (Eds.), (201). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535.
12. Campbell, B., Mann, W., Melénde-Ortiz, R., Streck, C., Tennigkeit, T., Christophe, B.C., Meijer, E., Wilkes, A., and Vermeulen, S. (2011). Agriculture and climate change: a scoping report. Meridian Institute, Bangkok, 98.

13. Biermann, F., Bai, X., Bondre, N., Broadgate, W., Chen, C-T. A., Dube, O.P., Jan Erissman, W., Glaser, M., van der Hel, S., Lemos, M.C., Seitzinger, S., Karen, C., and Seto, K.C. (2016). Down to Earth: Contextualizing the Anthropocene. Global Environmental Change, (39), 341-350.
14. Hasan, A., Pervaiz, A., and Raza, M., (2017). Drivers of climate change vulnerability at different scales in Karachi. International Institute for Environment and Development (IIED) Working Paper. IIED London, 10.
15. Fonteh, M. L., Samba, G., and Kiming, I. N. (2017). The Implications of Rainfall and Temperature Variations on Crop Farming in Kumbo Plateau, Cameroon. International Journal of Resource and Environmental Management. Vol. 2. No. 1. ISSN 2415 – 556X.
16. Barron, J., Rockstorm, J., Gichuki, F. and Hatibu, N. (2003). Dry spell analysis and maize yields for two semi-arid location in East Africa.Agril for Meteorol., 117:23-37.
17. Intergovernmental Panel on Climate Change-IPCC, (2021) Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 41.
18. Mathews, T., Mullan, D., Wilby, R.L., Broderick, C., and Murphy, C., (2014). The household economy approach: managing the impact of climate change on poverty and food security in Developing Countries. Climate Risk Management, 4 (5), 59-68.
19. Kinuthia K. J., Shadrack K. I. and Lenah N. (2018). Factors influencing farmer's choice of crop production response strategies to climate change and variability in Narok East Sub-County, Kenya. Journal of Natural Resources and Development, (8) 69- 77.
20. Tume, S.J.P., and Fogwe, Z. N. (2018). Standardised Precipitation Index Valuation of Crop Production Responses to Climate Variability on the Bui Plateau, Northwest Region of Cameroon. Journal of Arts and Humanities (JAH), Faculty of Arts, the University of Bamenda, 1 (2), 21-38.
21. Tume, S.J.P., Chiamba, C.Z., Sama, M.N., Ateh, E.N., Bailack, K.M., Suika, R.N., Lueong, L.A. and Jude,K. (2020). Climate Change and Food Security in the Bamenda Highlands of Cameroon. In: squires V., Gaur M, (eds) food security and land use change under conditions of climate variability pp107-124
22. Ayonghe, S (2001) Trends and Impact of Climate Change in Cameroon, Central Africa: Consideration for Renewed Ethics towards Resilience Options for Community.
23. Fontem, D.A, Demo. P, Njualem D.K., (2004). Status of potato production, marketing and utilization in Cameroon. In: Advances in Root and Tuber Crops Technologies for Sustainable Food Security, Improved Nutrition, Wealth Creation and Environmental Conservation in Africa (Mahungu NM and Manyong VM Eds). Proceeding 9th ISTRC-AB Symposium. 15 Nov. 2004. Mombasa, Kenya, 18-25.
24. Tume, S.J.P. (2022). Standardized Precipitation Index Valuation of Climate Change in Bamenda. Geology, Earth and Marine Sciences. 4(1), 1-6.
25. Rooy, M.P. (1965). A rainfall anomaly index independent of time and space. Notos, 14, 43-48.
26. Regional Delegation of Transport, North West Region (2017). Statistical Handbook on climate variability data. 165p.
27. Sub-Divisional Delegation of Agriculture and Rural Development, Bamenda III. (2022). Agricultural production extension in Bamenda III Sub-Division. 22p.

28. Abang, A. F., Kouamé, C. M., Hanna, R. and Fotso. A.K. (2014) Adaptations and Mitigation of the Climate Change, Cambridge: Cambridge University Press.