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Effect of Climatic Factors (Rainfall, Temperature) on crops Production (Sorghum, Sesame and Millet) under Traditional Rain-fed Subsector at White Nile State, Sudan

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Abstract

This study aimed to assess the impact of temperatures and rainfall on Sorghum, Sesame and Millet yield under traditional rain-fed subsector at the White Nile state, during the period (1970-2019) Data from secondary sources were used in this study. Climate data included rainfall and temperatures obtained from Sudan Meteorological Authority (SMA). Production data included time series data of Sorghum, Sesame and Millet yield were obtained from Ministry of Agriculture and Forestry, Statics division, Khartoum Sudan, Secondary data were analyzed using correlation, Cobb Douglas production function and simple regression analysis, The study found that the fluctuation of rainfall and temperatures during the study period had negatively affected of Sorghum, Sesame and Millet yield, which represent the food and cash crops in the state, the study recommended the introduction of short maturing cultivars.
Key words: temperatures, rainfall, Sorghum, Sesame, Millet, traditional rain-fed subsector, Cobb Douglas, Correlation, simple regression.

Introduction

Climate change refers to a change and variability of climate which affect directly or indirectly human activity altering the composition of the global atmosphere and crop and animal production systems. There is no doubt that climate plays a significant role in shaping the face of the earth and in determining the types of economic activities that human can practice. Realization of the human - climate relationships has led to a growing interest in the science of climatology especially in the tropical areas where the impacts exerted by the various climatic factors particularly rainfall and temperature are vital and effective *(Noah, 2016)*. Sudan's inherent vulnerability to climate change is captured by the fact that food security is mainly determined by rainfall, particularly in rural areas where more than 65% of the population lives. According to *(Sassi, 2012)* and *(Sudanese Ministry of Environment and Physical Development, 2007)*, rainfall supports the overwhelming majority of the Sudanese agricultural activities that constitute the main economic sector of the country. Almost all of the cultivated land, 95%, is under a rain-fed mechanized or rain-fed traditional farming system, which grow more than 70 % of the domestic cereal production. These in addition to increase in temperature beyond the optimum level (high temperature of about 26-30 C° and low temperature of about 10-15 C°) results in a decline in sorghum production *(Noah, 2016)*. On the other hand, agriculture and natural vegetation cover is often the first sector to be affected by the onset of drought due to the dependence on water resources and soil moisture reserves during various stages of crop growth *(Muna, 2012)*. Based on average seasonal rainfall, potential evapo-transpiration and according to the ratio of humid months to arid months and length of the growing season. Historically, average annual rainfall has declined from about 425 mm/year during the period 1941-1970 to about 360 mm/year in the period 1970-2000. This represents a decrease of annual rainfall of about 0.5% per year (*Sudan Meteorological*

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Authority - SMA). Climate change affects production of the corps in traditional rain fed sector of the White Nile State. According to the crops production characteristics, the lifecycle of a plant is divided into four stages: seeding, vegetative, flowering/ grain filling, harvesting, To clear the effect of climate change on crop production in the White Nile State, we have the following study which states the impact of climate change during the crops growing stages as follows: the stage wise results for rainfall- yield coefficients are in (Table 1)

Table 1: Sorghum and sesame yield outlook during the rainy season.

Life cycle	Months	C my (kg/ha mm)	
		Sorghum	Sesame
Seeding	May	9.61	7.64
	June	0.51	2.42
Vegetative	July	-1.74	-0.19
	August	2.8	-0.19
Flowering & filling	September	14.15	2.42
Harvesting	October	32.31	7.64

Notice: "c_my" is Coefficient Meteorological Yield, (*Ibrahim A.M., 2015*)

Presenting a brief on the description of the White Nile state being the area of the study. It also describes the method of data collection and analysis. Agriculture is extremely vulnerable to weather changes though crop yield is affected by natural and non-natural factors. The environment is one such natural factor which plays an important role in determining the yield. Changes in yield component may be a result of plant's response to stress at various stages of plant growth and development. The White Nile State accommodates both rain-fed and irrigated farming dominated by the former under a mechanized mode having high growth. Traditional rain-fed agriculture has rather humble growth while irrigated farming has remained almost stagnant. The rain-fed crop mix has sorghum as the major crop, which together with sesame and millet, from about 97% of the total area under this system. There are also other crops grown on a limited scale such as groundnut, water melon and guar. Irrigated farming is concentrated in agricultural schemes and small ones along the White Nile; both irrigated by pumps from the Nile. Crops there are again dominated by sorghum that occupies close to three quarters of the area, followed by wheat (18%) and cotton (8%). Groundnut existed till the late 1970s but has almost vanished since then. Major food security crops are sorghum, wheat and to a much lower extent millet. The problem of this study is to assess the effect of climate variability on the production of corps in the traditional rain-fed sector of the White Nile State. This because crop production of small producers in the state has been subject to continuous recurrent droughts and floods that had reduced crop yields and outputs. The example of main crops table in rain-fed traditional sector in the state (Table2).

Table 2: Sorghum, Millet and Sesame Production in White Nile State, Sudan,period 2010 - 2019

Sorghum				Millet				Seasme			
Cultivated (1000F)	Harvested (1000F)	Production (1000T)	Yeild (kg/fed)	C	H	P	Y	C	H	P	Y

09/2010	550	435	59	136	153	92	17	185	251	243	32	132
10/2011	415	291	78	268	46	32	16	195	198	154	24	158
11/2012	506	260	47	181	46	32	6	188	143	125	13	104
12/2013	565	450	122	271	89	75	14	187	330	310	34	110
13/2014	524	262	35	134	42	12	1	143	291	160	14	0
14/2015	485	364	65	180	82	77	12	160	356	305	41	135
15/2016	265	119	5	45	30	9	0	50	264	158	7	45
16/2017	545	392	64	152	75	60	6	88	248	206	21	103
17/2018	500	307	31	100	15	4	1	119	267	254	28	110
18/2019	735	450	81	180	53	40	7	175	300	210	22	105

Source: Ministry of Agriculture and Forestry, Statics division, Khartoum Sudan, 2020

The problem for the study phrased in the following question: "What is the impact of Climate variability factors (temperature and rainfall) on crop production in the traditional rain-fed Sector in White Nile State, Sudan?"

To assess the effects of temperatures and rainfall on sorghum, sesame and millet yield under traditional rain-fed subsector at White Nile State,

Previous Study

(*B Sultan, al, 2013*) Study stated that Sub-Saharan West Africa is a vulnerable region where a better quantification and understanding of the impact of climate change on crop yields is urgently needed. The study has appliedpractices in Senegal, Mali, Burkina Faso and Niger. The showed a reasonable correlation with observed yields of sorghum and millet under a range of cultivars and traditional crop management practices. Also showed a negative impact on yields, up to −41 % for +6 °C / − 20 % rainfall. Moreover, the potential future climate impacts on yields are very different from those recorded in the recent past. This is because of the increasingly adverse role of higher temperatures in reducing crop yields, irrespective of rainfall changes. When warming exceeds +2 °C, negative impacts caused by temperature rise cannot be counteracted by any rainfall change.

Regarding (*B Sultan, al, 2013*) results of sorghum and millet, we agree with the study results about negative impact on two crops.

(*Ibrahim A.M, 2015*) study addressed the impact of the weather change mainly rainfall on the yields for the staple crops (sorghum and sesame) in a traditional rainfed sector in the White Nile State of Sudan. Time series rainfall and grain yield data for 10 years (2001-2010) are analyzed. The results indicate that an increased availability of water enhanced productivity in terms of grain yield. An annual increase in average rainfall to 2.62 mm during crop maturing stage (harvesting stage) resulted in sorghum and sesame yields higher to 32.31 kg/ha, and 7.64 kg/ha respectively.

Referring to (*Ibrahim A.M, 2015*) results of sorghum and sesame, we disagree with the short period of the study (10) years would not give a time series suitable for analysis of changes in climate factors and its impact on crops.

(*YousifElnourYagoub, al, 2017*) study, analysis of precipitation and temperature time series revealed that the annual precipitation was decreasing while the temperature was increased in the study area. Sorghum yield showed a significant positive relationship with precipitation during July and October, moreover, a significant positive relationship between Sesame yield and precipitation was observed during July. A significant negative relationship between Sorghum yield and mean temperature was observed during the rainy season (July to October). Thus, the researcher ultimately suggest that in the Gadarif State, policy makers must strive for an increase in yield per unit area by using sufficient fertilizers along with the gradual increment in tendencies of grain production through expansion of the cultivated area.

The results of (*YousifElnourYagoub, al, 2017*) gives an agreement with our study results.

(Abbas Elsir Mohamed E, and others 2018) study concluded that, Gezira state is affected and impacted by climate change, declining rainfall and increased maximum temperatures as a result of climate change during the last five decades has negatively affected sorghum yield in the traditional rain-fed subsector of the Gezira state.

*Regarding (Abbas Elsir Mohamed E, and others 2018)*results of sorghum, we agree with the study results about negative impact the crop yield.

In (*Amal Ahmed Osman Abubakr, 2018*) study, trend analysis in Gedarif recorded non-significant reduction in the annual rainfall during the period 1970 - 2015. On the other hand, Gezira and Gedarif states recorded highly significant increases in minimum and maximum temperatures. Sorghum yield in the two states were gradually decreasing during the period 1970 to 2015. Correlation coefficients showed clear relationships between sorghum productivity and climate factors in the two states. The multiple regressions showed significant and positive effect of climate factors on sorghum productivity. This result supports the fact that an increase in rainfall improves sorghum productivity, the maximum temperatures have a negative and significant effect on the productivity of sorghum.

Referring to (*Amal Ahmed Osman Abubakr, 2018*) study, we agree with the results of rainfall, and disagree with the results of temperature.

The study methodology:

Study area: The State lies between latitudes 12^{o} and 13.3^{o} (N) and longitudes 31^{o} and 33.3^{o} (E), straddles the White Nile South of Khartoum and borders six states (Fig.1). It has a population of about 1.731 million growing at a 2.5% rate and distributed over eight localities, namely Rabak, Kosti, Alquiteina, Edduim, Umrimta, Algabalain, Alsalam, and Tendelti (Table 1), with a total area of 39,704 km2, the average population density can be computed at 44 persons/km2. Kosti is the most populated locality followed by Edduim, Alquiteina and Rabak, but Kosti and Rabak are the most densely populated localities. The State is home to significant numbers of refugees of about 153,000 in 2006, forming nearly 10% of the population and also a transit point for IDPs returning to the south and South Kordofan. Most of these IDPs have been settled in, around Kosti and in many other camps.

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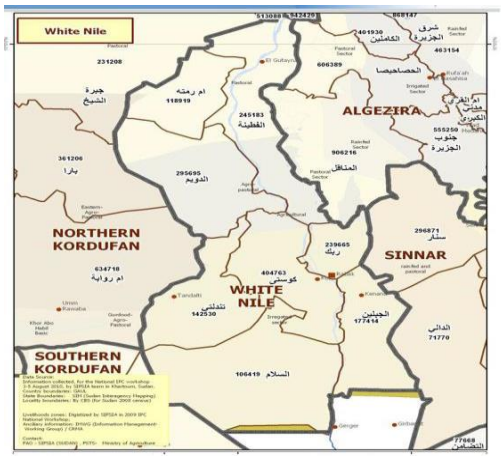


Figure 1: White Nile State

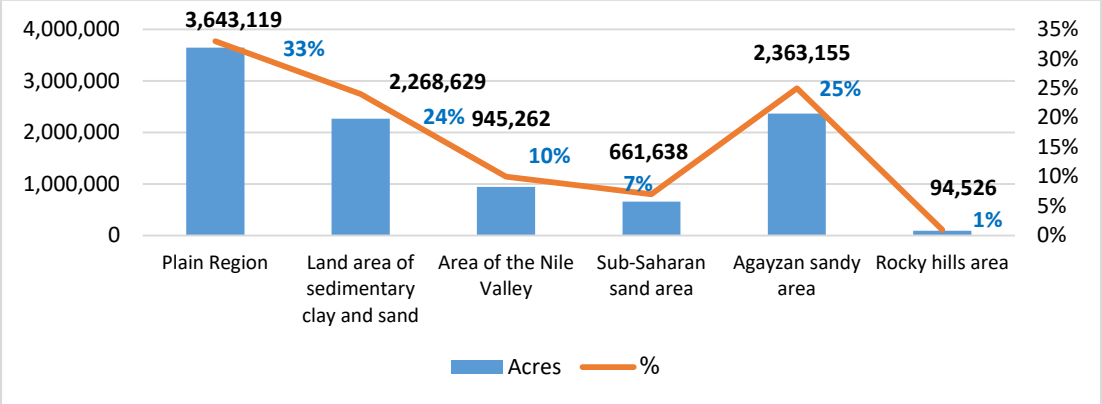


Figure (2). The geological formation of White Nile state
Source: Central Sector Commission and UNDP, 2010

Table (2). Agro-climatic zones of the White Nile state

Agro-ecological zone	Seasonal rainfall (mm)	Humid months(#)	Growing season length (days)
Arid	200-300	2-3	60-90
Semi-arid	350-750	3-4	90-120

Source: A. K. Osman et. al, 2012

Data sources and collection method: Historically, annual rainfall, maximum and minimum temperature of White Nile States for the period 1960-2019 obtained from Sudan Meteorological Authority (SMA), Basic Corp production data included time series data of Sorghum, Sesame and Millet yield for the period 1970-2019 of The Traditional Rain-Fed subsector in White Nile States were obtained from Ministry of Agriculture and Forestry, Statics division, Khartoum Sudan,

Data Analysis &Analytical tools: Descriptive statistics, correlation, simple regression and Cobb Douglas production function were main analytical tools used in this study.

The correlation analysis was used to measure the linear relationship between sorghum yield and climate factors. The value of correlation coefficient (r) range from -1 to +1. The value of (r) near zero indicates absence of correlation between variables while a value near +1 and -1 indicates a high positive or negative level of correlation, respectively.

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Regression analysis is used to relate crop yield data to weather data considering the same area *(Parry et. al., 1989)*. It is useful approach in providing quite effective estimates of crop yield when crop yield is affected by weather factors such as rainfall or temperature *(Parry et al, 1989)*. Thus, regression analysis is used in this study to estimate impact of temperature and rainfall on sorghum productivity. It is more likely that relationship between climate variables and crop yield is non-linear as crop growth increases with a rise in temperature upto a certain limit, after that, crop growth may be adversely affected by an increase in the temperature. The same is the case of rainfall impact on crop productivity. Simple regression analysis was used to estimate the trend of the historical climate data to detect whether there is a climate change in the study area as postulated by seasonal rainfall, monthly minimum and maximum temperatures during the period 1970-2019 from kosti weather stations in the state. The linear trend is simply represented by the following equation:

$Ty = a + bx$

Where:

Ty = trend values of the climate variables i.e., seasonal rainfall, minimum and maximum monthly temperature in the main weather station in White Nile states. *a* = intercept or estimated value when *x* equal to zero *b* = slope of line or average change in *Y* per unit of time x = time factor (years) from 1970-2019. The non-linear form of regression analysis, Cobb Douglas production function, was selected for being easy to estimate and interpret the estimates and for its appropriateness in the situation when observations are not large (Cobb and Douglas, 1928). Cobb Douglas production function can be written as:

$Y = b0\ Tmax^{b\,1}\ Tmin^{b2} P^{b3} U_t$ 1

Where *Y* is a dependent variable (sorghum yield in kg). *Tmax* is maximum temperature, *Tmin* is minimum temperature during the rainfall season and *P* is seasonal rainfall in White Nile state represent the independent variables included in the regression analysis. *bl, b2* and *b3* are parameters to be estimated. *b0* is constant term and U_t is the error term with zero mean and constant variance. This non-linear form of Cobb Douglas production function can be estimated through ordinary least squares by taking natural log on both sides of equation (1). Estimates of this form of production function give direct elasticities of variables. Log linear form of Cobb Douglas production function used in the present study is given as $\log Y = b_0 + bj_ \log T_{max} + b_2 \log T_{min} + \text{ba} \log P + U_t$ 2

Results and Discussions:

Developing countries account for roughly 90 % of the world's sorghum area, and generate 70 % of total output *(Noah, 2016)*. However, Sorghum is the major cereal crop and considered as the most important, with more than 80% of the crop grown in the rain-fed subsector *(Faki et al., 1995)*, and main pillar of food security in the country providing about 60% of the quantity of the cereal consumed *(Rajaa, 2006)*. Sorghum area under traditional rain-fed in the White Nile state was growing during the period 1980-2019, reaching about 0.612 million feddan in season 2019,started with 0.165 million feddan in season 1980, reaching 0.735 million feddan in season 2018, as it has been recorded during the same period (Table 3 and Fig. 3).

Sorghum: is a drought resistant crop with a very efficient, well-branched root system containing considerable amounts of silica that prevent the plant from collapsing in dry soils. Sorghum can also reduce its transpiration during periods of water shortage by rolling its leaves and by stomata closure; in these conditions, it can remain dormant

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while other crops perish, and when the rains resume it recovers rapidly. Sorghum needs at least 300-380 mm water during the growing period. It is one of a few crops that can withstand short periods of water logging, therefore it is popular on heavy clay soils. Bird damage is one of the main causes of crop loss in sorghum, and bird susceptible varieties may not be able to manage any yield at all. Insects and diseases are another major source of crop losses (*Acland, 1971*).

Theoptimal environment for sorghum is warm-zone cereal grown in regions where high temperature and low rainfall, during late summer and early autumn *(D. Silungwe et al, 2012)*, While Sesame is almost entirely cultivated under rain-fed in the Sudan. It is grown in the (300 - 600 mm) in general, (380 - 510 mm) in specific, rainfall areas and with (500 mm) excellent crops are produced. However, a rainfall up to 800 mm can be tolerated if soils are well drained, it need (90 - 120 day) for forstree.Sesame is moderately drought resistant crop. Moist conditions are necessary during the early stages of growth. Most varieties of sesame are photoperiod sensitive. Sesame is very intolerant to water-logging but diseases seldom do serious damage (*Acland, 1971*).

Millet, known as "Dukhun", coming as the second most-important cereal cropafter Sorghum, in both studied area and total production. The grain is consumed as human food. The stalks can be used as feed for animals but they are mostly used as building material or fuel.Millet is a drought and heat tolerant crop capable of producing grain in regions of low soil fertility and limited moisture, where other summer cereals like sorghum and maize, may fail, it occupies the marginal low-rainfall areas. This is mainly due to its extensive and more efficient root system, as well as its high ability to produce tillers. Although the crop is grown in areas where rainfall ranges between 200 mm to more than 1000 mm, most of it occurs in areas receiving 250-700 mm. Most of the Millet production is centered in the extensive sandy soils “Goz”. These are marginal areas with less than 400mm rainfall. The crop is almost exclusively grown under rain-fed conditions, with about 98% of it being produced under traditional farming practices, mostly using local varieties. (*SENAS, Online*)

Table (3). Sorghum, Sesame and Millet cultivated area, production and yield of traditional rain-fed subsector in White Nile state due the period 1970 – 2019

Year	Sorghum			Sesame			Millet		
	Area Cultiv.	Production (1000 ton)	Yield (Kg/fed)	Area Cultiv.	Production (1000 ton)	Yield (Kg/fed)	Area Cultiv.	Production (1000 ton)	Yield (Kg/fed)
1970	360	99	341	181	31	190	65	10	213
1980	165	28	200	48	3	75	108	15	188
1990	247	9	95	140	2	36	21	18	83
2000	155	20	211	240	12	67	136	5	93
2010	415	78	268	198	24	158	46	16	195
2019	612	61	143	718	45	90	30	4	150

Source: Ministry of Agriculture, White Nile state, Information Centre, 2019

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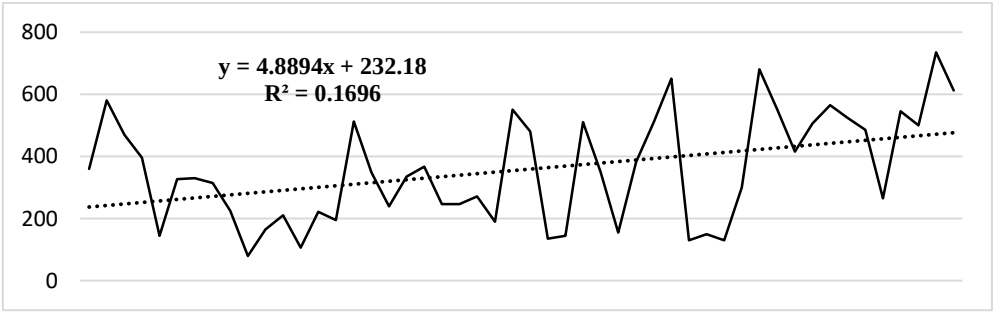


Figure (3). Sorghum cultivated area trend in White Nile traditional rain-fed subsector, period 1970 – 2019

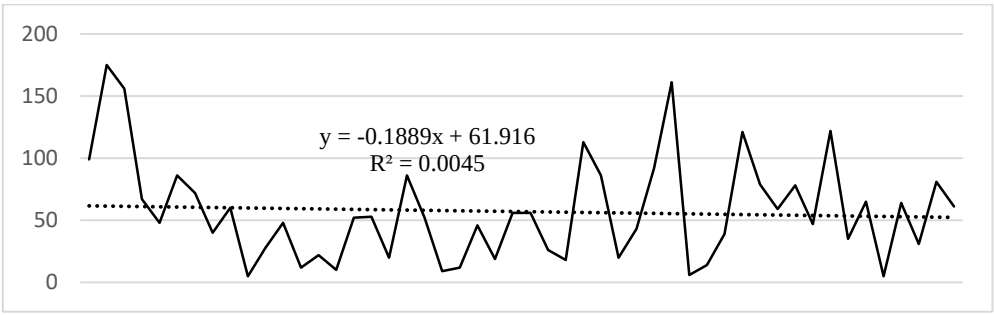


Figure (4). Sorghum Prod. trend in W. Nile trad. rain-fed subsector during the period 1970 - 2019

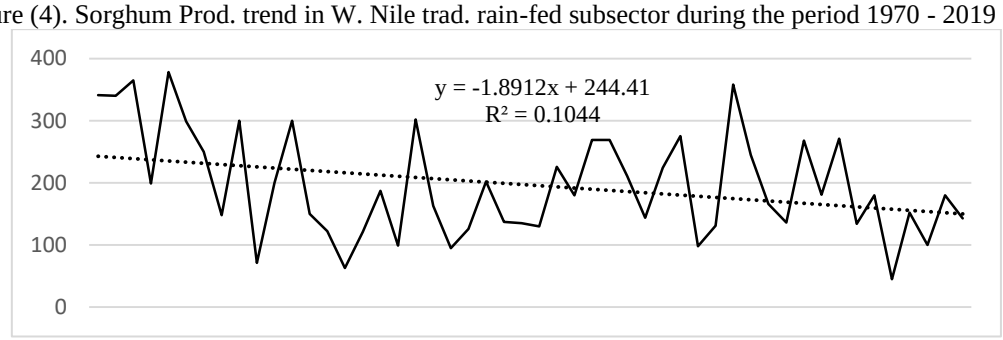


Figure (5). Sorghum Yield trend in White Nile traditional rain-fed subsector, period 1970– 2019

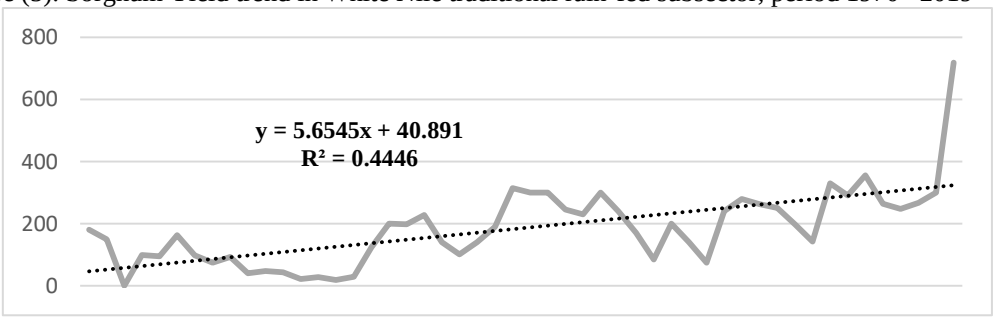


Figure (6). Sesame cultivated area trend in White Nile trad. rain-fed subsectorperiod 1970 – 2019

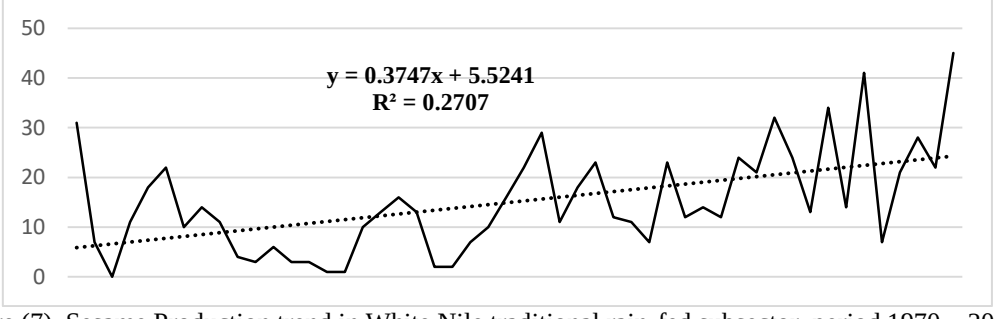


Figure (7). Sesame Production trend in White Nile traditional rain-fed subsector, period 1970 – 2019

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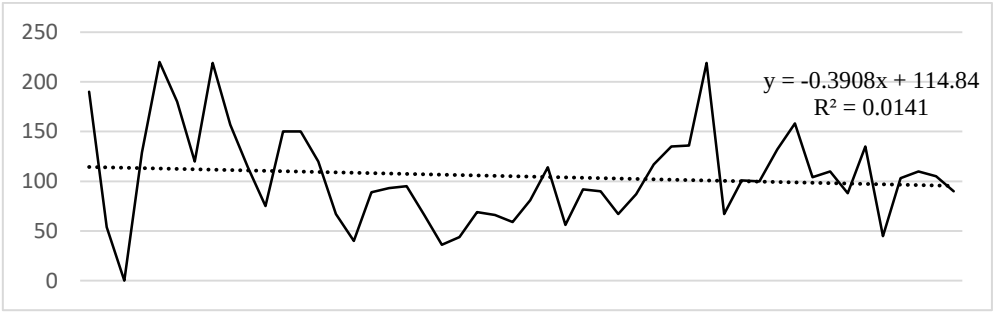


Figure (8). Sesame Yield trend in White Nile traditional rain-fed subsector, period 1970 – 2019

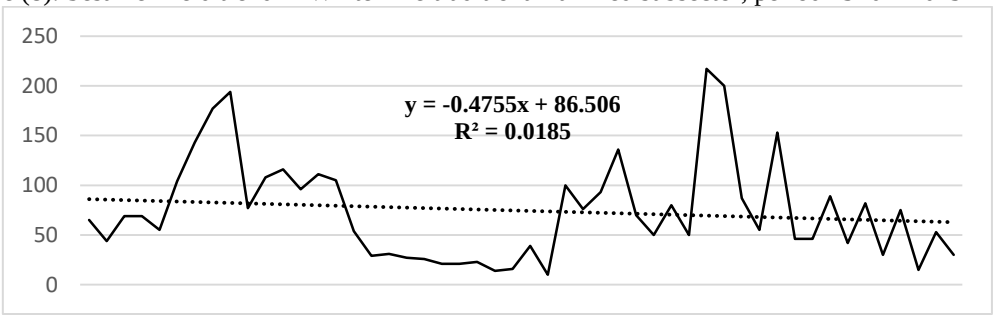


Figure (9). Millet cultivated area trend in White Nile trad. rain-fed subsector, period 1970 – 2019

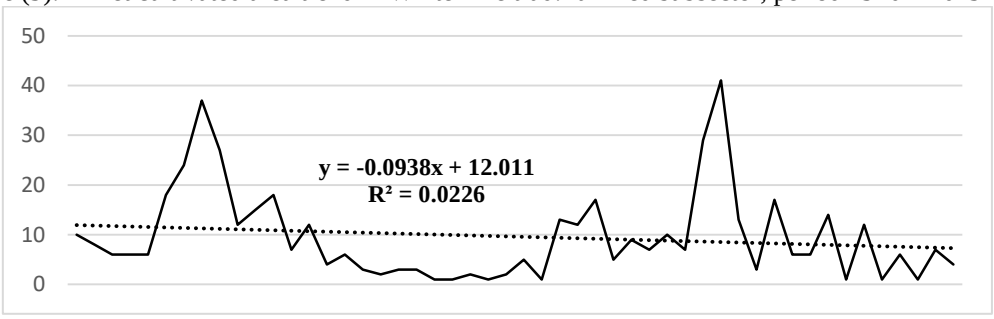


Figure (10). Millet Prod. trend in White Nile traditional rain-fed subsector, period 1970 – 2019

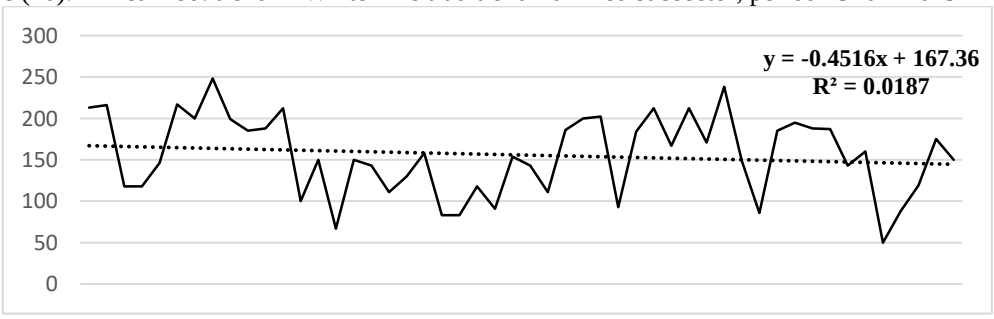


Figure (11). Millet Yield trend in W. Nile traditional rain-fed subsector during the period 1970 - 2019

Results showed that White Nile state is subjected to significant increasing in seasonal rainfall, and significant volatilityin monthly according to: significant high increasing in the months of July and August, while accompanied with high reduction due the month of September, and slight increasing due the month of October, during the period 1970 - 2019. This fact explains that, White Nile state is affected and impacted by climate change (Table 4). Fig. (12&13).

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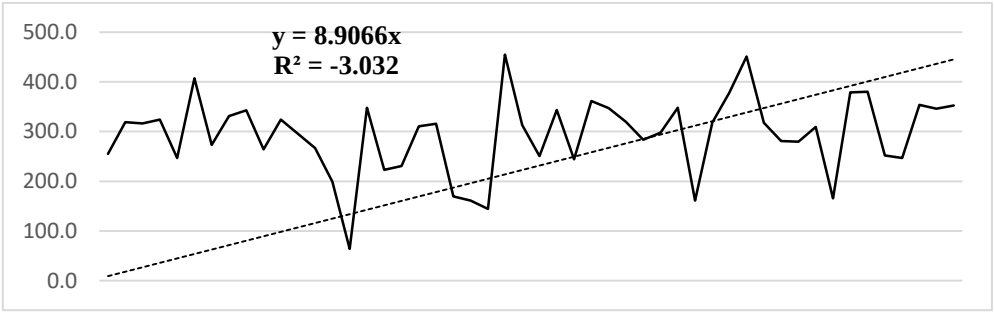


Figure (12). Seasonal Rainfall in White Nile state(1970 – 2019)

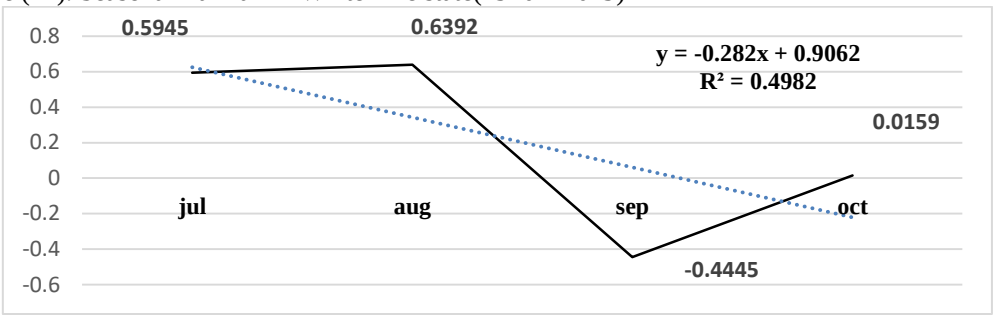


Figure (13). Monthly Volatility of Rainfall in White Nile state (1970 – 2019)

Table 4. Trend of the seasonal and monthly rainfall in White Nile state, 1970 - 2019

Rainfall	Trend	P-value
Seasonal rainfall	8.9066	*0.0015
Monthly rainfall	-0.0282	*0.0018

Source: author's computation

* asterisks on the value of the parameters indicate it's significant at (p = 0.001, 0.05) level of significance, respectively**.**

Regarding the maximum and minimum temperatures, White Nile is subjected to non-significant increase in maximum and significant increase in minimum temperature through over Autumn season due the period 1970-2019 (Table 5).

Table 5. Trend of maximum and minimum temperatures in White Nile state, 1970- 2019

Autumn Season	Trend	P-value
Maximum Temp.	1.0557	0.4826
Minimum Temp.	0.7029	0.0372*

Source: author's computation

* asterisks on the value of the parameters indicate it's significant at (p = 0.01'0.05) level of significance, respectively**.**

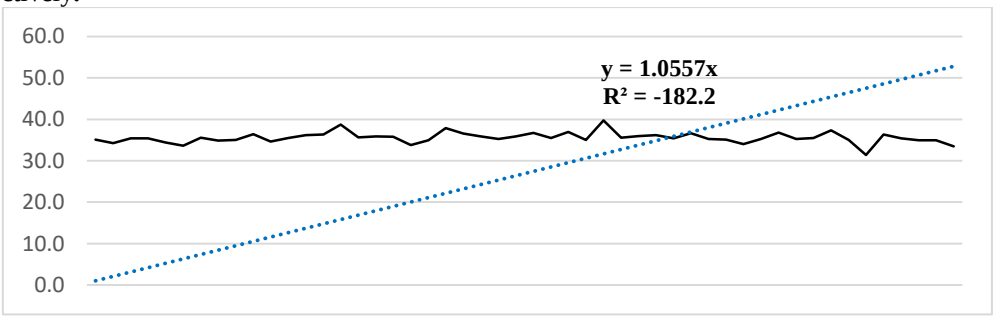


Figure (14). Maximum Temperature average during Autumn season in White Nile state (1970 – 2019)

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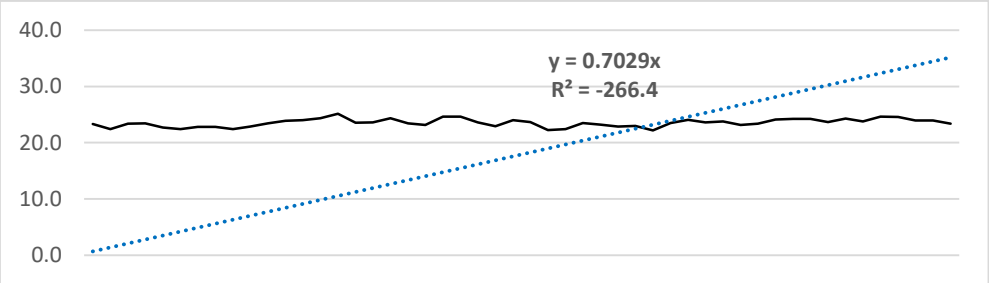


Figure (15). Minimum Temperature average during Autumn season in White Nile state (1970 – 2019)

Correlation analysis showed a positive and significant relationship between sorghum yield and rainfall (0.2998), and negative but high significant relationship between sorghum yield and minimum temperature (-0.4858). This means that an increase in rainfall enhances sorghum production; while its decrease results in poor sorghum yield. On the other hand, maximum temperature showed a negative andsignificant relationship with sorghum yield with a correlation coefficient of (-0.3120). This implies that an increase in temperature beyond the optimum level (high temperature of about 26-30C° and low temperature of about 10-15C°) coupled with a declining rainfall resulted in low sorghum yield, while Correlation showed a positive and non-significant relationship between sesame yield and rainfall (0.1089), and non-significant relationship between sesame yield and minimum temperature (0.1141). for the maximum temperature showed non-significant relationship with Sesame yield with a correlation coefficient of (0.2700). also Correlation showed a positive and non-significant relationship between Millet yield and rainfall (0.2629), and significant relationbetween Millet yield and minimum temperature (0.0014). for the maximum temperature showed non-significant relationship with Millet yield with a correlation coefficient of (0.1657).

Table 6. Correlations coefficients between crops yield and climate factor in White Nile state, 1970 - 2019

Source: author's computation

Climate factors	Sorghum		Sesame		Millet	
	Correlation	Sig.	Correlation	Sig.	Correlation	Sig.
yield & Max. temp.	-0.3120	0.0273	0.2700	0.0578	0.1657	0.2501
yield & Min. temp.	-0.4858	0.0006	0.2262	0.1141	0.4389	0.0014
yield & Rainfall	0.2998	0.0343	0.1089	0.4516	0.2629	0.0651

Results showed that the average of both minimum and maximum temperatures in autumn season during the period 1970 - 2019 in the White Nile state was 23.53C^{o} and 35.57 C^{o}, respectively. Thus, the maximum and minimum temperature may be over the optimum level for sorghum level (high temperature of about 26-30 C° and low temperature of about 10-15 C°). The average seasonal rainfall (286.57mm) in the White Nile state is appropriate for drought tolerant and early maturing cultivars of sorghum (Table 7).

Table 7. Descriptive statistics of sorghum yield and climate factors in White Nile state, 1970 - 2019

Climate factors	Mean	Std. Deviation
Maximum temperature (in C^{o})	35.57	1.31
Minimum temperature(in C^{o})	23.53	0.70
Rainfall (in mm)	293.28	77.64
Sorghum yield (in kg/fed)	196.18	85.34
Sesame yield (in kg/fed)	104.88	48.00
Millet yield (in kg/fed)	155.84	48.13

Source: author's computation

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Sorghum yield under traditional rain-fed subsector in the White Nile state during the period 1970 - 2019 was regressed on the amount of seasonal rainfall, minimum and maximum monthly temperature for the same period to trace the effect of these climatic factors on sorghum yield. Description of the variables needed for sorghum yield model showed in Table 8.

Table (8) Description of the variables needed for crops(sorghum, Sesame & Millet) yield models

Variable	Description (from 1970- 2019)	Type	Expected sign		
			Sorghum	Sesame	Millet
Dependent variable	Average of Crop yield in kg/fed				
Independent variables					
Maximum temperature	Average of max. temperature in C^o	Continuous	-	-	-
Minimum temperature	Average of min. temperature ^oC	Continuous	-	-	-
Seasonal rainfall	Average of seasonal rainfall in mm	Continuous	+	+	+

Source: author's computation

Results of Cobb Douglas production function are given in Table (9),which show that the three coefficients of climate variables for the three crops were statistically different from zero. Not all coefficients of climatic variables had the expected signs, where Sorghum and Millet showed positive sign to Maximum temperature in autumn, and the three crops yield give negative sign with the average of seasonal rainfall. The coefficient of maximum and minimum temperature was statistical non-significant for the three crops, while the coefficient of rainfall was statistical significant for Sorghum and Millet corps, and non-significant for Sesame crop. Significance of the model indicated by F value depicted that overall regression model was good for the present of data for Sorghum and Millet crops. Value of R-square showed that variables included in the model explained variation in crops yields. However, in referring with the optimal level of temperature and rainfall of the three mentioned crops, the results of this regression showed the crops yield where affected by climate change factors in different levels as shown in (tab. 8), In White Nile state, during Autumn season, the module of Cobb Douglas production function (tab. 8) explain (32.12%) ofthe regression resultsfor sorghum yield in consideration of significant negative correlation sign for the relation between Sorghum yield with Max. & Min. Temp., and significant positive with rainfall (Tab.5), for Millet yield explain (23.05%) with significant positive correlation sign for the relation with Max., Min. Temp. & rainfall, while explain only (03.44%) for Sesame yield with non-significant positive correlation sign for the relation with Max., Min. Temp. & rainfall.

Table (9) Cobb Douglas production function for crops (sorghum, Sesame & Millet) yield models

Model	Sorghum		Sesame		Millet	
	Coefficient	Significant	Coefficient	Significant	Coefficient	Significant
Constant	34.8265	0.0018	27.6785	0.1856	18.3733	0.0338
Maximum temperature in autumn	0.1120	0.6327	-0.1995	0.66629	0.1799	0.3366
Minimum temperature in autumn	- 2.3673	0.2291	-3.7373	0.3298	-0.0585	0.9799
Average seasonal rainfall	- 6.8629	0.0032	-2.8485	0.5114	-4.4132	0.0155
R_2	0..3212		0.0344		0.2305	
Adjusted R^2	0.2769		-0.0286		0.1803	
F	7.2543	0.0004	0.5464	0.6530	4.5932	0.0068
N	50		50		50	
Durbin Watson	109.9922		138.9767		38.7741	

Conclusion

The study concluded that the increase of rainfall and shorten of the rainy day's season, also the increase of maximum and minimum temperatures as a result of climate change during the last five decades has negatively affected Sorghum, Sesame and Millet yield in the traditional rain-fed subsector of the White Nile state. To mitigate the effects of climate change, the study recommended the introduction of short maturing cultivars.

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