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Impact of Climate Change on Natural Resources at EL-Damazine and AT -Tamadon Localities Blue Nile State

Hanadi I. O. Babikir[1], Muna M.M. Ahmed[2] and I. Bushara[3]

[1]University of El-Geizera, Sudan
[2]Institute of environmental studies, University of Khartoum, Sudan
[3]Department of Animal Production, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan

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Corresponding Author:
Ibrahim Bushara
bushara3000@yahoo.com

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ABSTRACT

Adaptations of small scale farmers to climate change impact on crop production under rainfed conditions at the Blue Nile state were investigated. The study focused of two localities El-Damazine and Al-Tamadon at Blue Nile state, Sudan, during the years 2010 - 2011. Eleven villages (18655 households) were selected according to a sampling technique with sample size of 200. Standardized Precipitation Index (SPI) was used to detect drought in areas cultivated, harvested and the grain yields for the years from 1971 to 2010. Crop-climate model was used to isolate and quantify the effects of the various factors that influence crop production (sorghum, millet and sesame). Field visits and direct observations of farmers' different practices were recorded. Secondary data utilized Government documents and records in the relevant departments (ministry of agriculture and statistical bureau at the Blue Nile state, Sudan metrological authority), (ii) written reports, thesis, pamphlets, papers, articles, photos and maps, aerial photography and cartographic material, (iii) data on the characteristics of the population and aspects of economic activity in the region. The data analysis adopted the descriptive Statistical Package for Social Science (SPSS, version 16). Regression analysis was used to assess the effects of climatic variations on crop production; paired t-test was used to compare production between the beginning and end of each season. SPI showed a moderate to extreme drought events during the years (from 1972 to 2008), with shorter growing season. Statistical regression model that correlated rainfall to crop production, showed clear decline in crop production with various degrees. Several coping mechanisms were observed during the field visits as could be envisaged in early sowing to have the benefits of the early rains and to repeat sowing later in case of seed germination failure. Sowing of many seeds within a hole to make sure that some were not blown by wind, but in case if many succeeded to grow, some would be pulled out (Shelikh). Mulching was done by leaving stalks on the ground to maintain soil moisture. Farmers have storage pits to save seeds for the coming season. They also have the indigenous knowledge of predicting drought of what is known as '*Traditional Divisions of Lunar*'. It could be concluded that rain fed agriculture is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impact of climate change mainly determined by rainfall

and warming of air temperatures. Adaptations of farmers under rain fed conditions to climate change my take different forms to hedge risks against extreme crop failures.
Keywords: Adaptation, Climate, Farmers under, Blue Nile State.

INTRODUCTION

Due to the dependence on water resources and soil moisture reserves during various stages of crop growth, agriculture is often the first sector to be affected by the onset of drought (Narasimhan and Srinivasan, 2005). Sudan warming of more than 1 degree Celsius is equivalent to another 10–20 percent reduction in rainfall for crops. Also Rainfall reductions can be visualized by combining the observed 1960–2009 changes with predicted 2010, 39 changes, based on persistence of the observed trends of rainfall declines range from -150 to -50 mm across the western and southern portions of the country. Observed changes alone account for 63 percent of the change magnitudes. South Darfur exhibits the largest declines, followed by Blue Nile. The magnitude of recent warming is large and unprecedented within the past 110 years. It was estimated that the 1975 to 2009 warming was more than 1.3°C for southern Sudan and more than 1°C within the extended Darfur region (Funk, 2011).

Blue Nile depends on agriculture whose production is dictated, to a large extent, by climate. Farming is now becoming even more difficult and risky because of greater unpredictability in the timing of rainy seasons and the pattern of rain within seasons, making it more difficult to decide when to cultivate, sow, and harvest, and needing more resources to seize the right time for planting, and to maintain crops and animals through dry spells (Reid, 2009).

Many people dependent on rain fed agriculture are highly vulnerable to both short-term (two to three weeks) dry spells and long-term (seasonal) drought and thus are reluctant to invest in agricultural inputs that could increase yields. This situation will become worse for many small farmers with climate change. Traditional knowledge is an important element of climate risk management. Farmer’s local adaptation already happens and could provide a basis for effective strategies. Local knowledge and innovation are often the basis for spontaneous responses to extreme events (IFAD, 2008). The present study focused on traditional farming system as it is the most affected by climate change and land mismanagement. The study also investigated adaptations undertaken by farmers to cope with climate change; this was done by direct field visit observation.

MATERIALS AND METHODS

Area of the Study

The study focused of two localities (El-Damazine and Al-Tamadon; lat 11^{o} 55’ and 12^{o} 45’N, Long 33^{o} 45’E) during the years 2010 – 2011. According to the ministry of agriculture at the Blue Nile arable lands in Blue Nile State are estimated at 6 million feddan, but current cultivated land is about 1.5 million feddans. Three systems of agriculture can be identified which depends on machinery: mechanized farming is done by large companies and commercial farmers which are very common in the state. The Arab Authority for Agricultural Investment and Development (AAAID) has adopted a program zero-tillage cultivation system. The system applies integrated technology packages and mechanization. Non-mechanized traditional farming system is undertaken by small scale farmers. Farms plots are located around villages at a distance of approximately 1 to 2 km. Although the area used for cropping varies from 3 -5 for each household. Farmers would extend cultivated areas at the expense of rangelands as their lands become more and more degradable.

Data Collection

Primary Data

Small Scale Farmers' Selection and Field Visits

Out of the six localities in the Blue Nile state, two were selected (At-Tadamon and El-Damazinee). Eleven villages were randomly selected from each locality where 200 families were randomly selected. The direct observations included visiting agricultural fields for documentation of traditional farming practices such as land preparation, seeding and weeding in addition to soil type and water resources documentations. Coping mechanisms with climate change were observed and recorded.

Standardized Precipitation Index (SPI)

Drought occurrence is monitored using the Standardized Precipitation Index (SPI), is calculated by the difference between the precipitation data and the mean for that particular time scale, and dividing by the standard deviation (Hayes *et al.*, 1999). Positive SPI values indicate greater than median precipitation (wet condition), while negative values indicate less than median precipitation (i.e. drought).

Crop-Climate Model

The study adopted the modeling approach in examining the impact of climate on agricultural production. Crop-climate models may be considered as simplified representations of the complex relationships between climate and crop performance. In that sense, crop-rainfall models are the quantitative tools that can be used to translate a climatic perturbation into a tangible biophysical effect. Such models attempt to isolate and quantify the effects of the various factors that influence crop production. In the present study, the regression model was used to assess the effects of climatic variations on crop production in the study area. The crops selected for analysis were sorghum, and sesame. The choice of these two crops was based on their importance both in the local diet and in their widespread cultivation throughout the study area while millet was avoiding for some missing parameters data.

Areima model

Areima model is used to predict crop production through the years (2012-2018). Forcast Fitted Trend Equation used:

$$\mathbf{Yt = 1.36691 - 7.64E\text{-}02 \times t + 2.64E\text{-}03 \times t \times 2}$$

Where: Y = yield, t= time series

Secondary Data

Secondary data included (i) Government documents and records in the relevant departments (ministry of agriculture and statistical bureau at the Blue Nile state, Sudan metrological authority), (ii) written reports, thesis, pamphlets, papers, articles, photos and maps, aerial photography and cartographic material, (iii) data on the characteristics of the population and aspects of economic activity in the region.

Statistical Analysis

The data analyzes adopted the descriptive Statistical Package for Social Science (SPSS) (version 16). Regression analysis was used to assess the effects of climatic variations on crop production; paired t-test was used to compare production between the beginning and end of the season (Mead and Curnow, 1983).

Statistical Regression Model

The regression model was used to assess the effects of climatic variations on crop production in the study area. Relationship between the dependent (crop production) variable and the independent variable (rainfall) is represented by equation: $Y = a + bX + e$; where Y = dependent variable; a = intercept on y-axis; b = partial regression coefficient of the independent variables; X = independent variable; e = the random error term representing the proportion of unexplained variation. The dependent variables were regressed singly on the independent variables to avoid the problem of co-linearity.

RESULTS

Impact of Climate Change on Crop Production

Fluctuations in crop production were done for ten years (1972 – 2011). Sorghum showed a clear decline in production with time series (Figure 1). Sesame showed the same trend with one peak around 2001 (Figure 2). Millet production showed less fluctuations but sharp declines 2009 and 2012 (Figure 3). Figure 4 shows the differences among the different crops' yields and at and before 2010. It could be seen that sorghum and millets had nearly similar higher yields compared to sesame; however, the drop in yield was the highest for sorghum. The paired t. test statistics was carried out for every crop yield at and before the year 2012, it was found that there was a significant deference (P< 0.000) for all yields.

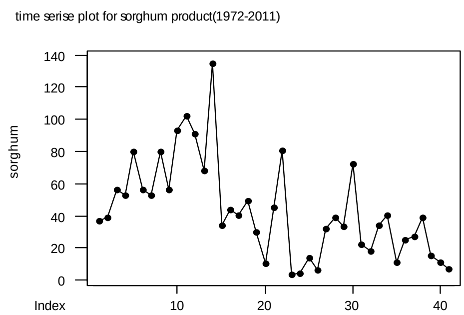

Figure 2: Fluctuations in millet production

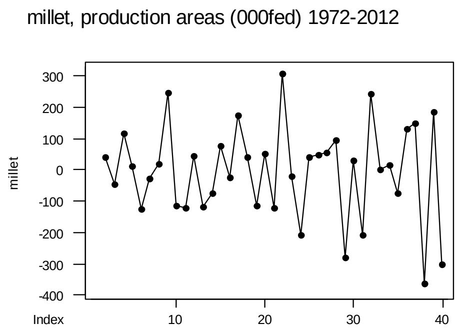

Figure 1: Fluctuations in sorghum production

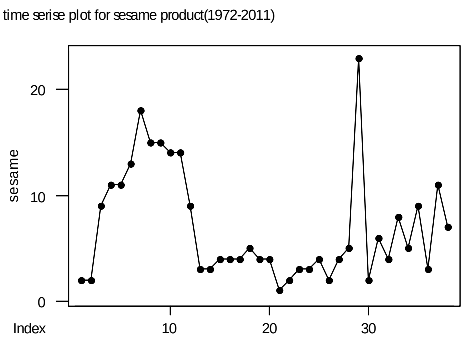

Figure 3: Fluctuations in sesame production

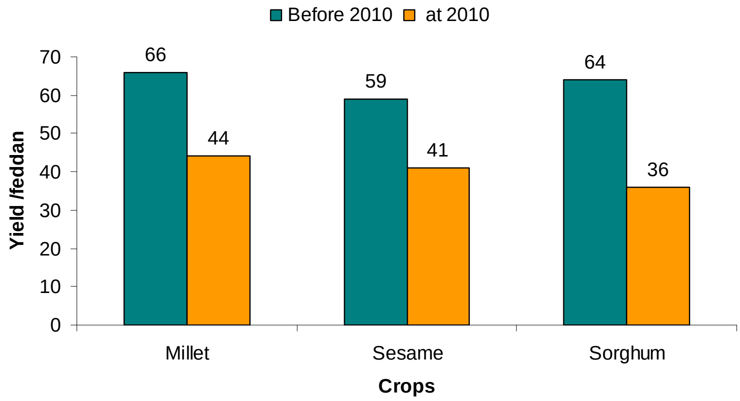

Figure 4: Comparison between crop yields for sorghum, sesame and millet at and before 2012

Standardised Precipitation Index (SPI)

SPI was used to detect drought which affect changes in areas of crop production (areas cultivated, areas harvested and the grain yields) for the years 1971-2010. High SPI value close to 3 means heavy precipitation, medium SPI value close to zero, low SPI value closer to -3 means low precipitation or drought (Table 1). The drought index showed that there was moderate to extreme drought events during the period 1972- 2008.

Table 1: Classification scale for SPI values

SPI	Category
2.00 and above	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.00 to –1.49	Moderately dry
-1.50 to –1.99	Severely dry
-2.00 and less	Extremely dry

Farmers' Adaptation

Main activities carried by small scale farmers is shown to be agriculture (54%), agriculture and animal husbandry (33%), and animal husbandry alone and others which constituted very little percent. Starting agricultural activities for 11 – 15 years showed the highest percent, followed by those practicing the activity for more than 16 years (Table 2).

Table 2: Respondents reporting main activities and starting of the activities

Main activities			Starting of the activities		
Items	**Frequency**	**Percent**	**Items**	**Frequenc y**	**Percent**
Agriculture	105	54.3	(1-5) year	15	7.5
agriculture and grazing	67	33.9	(11-15) year	104	52.0
Grazing	9	2.7	(6-10) year	10	5.0
Others	21	9.1	more than 16 year	71	35.5
Total	200	100.0	Total	200	100.0

This was shown by the fact that most of the respondents were positive about practicing agricultural activities while least was negative about practicing other activities (Table 3).

Table 3: Respondents reporting adopted other activities

Items	Frequency	Percent
No	162	82.2
Yes	38	17.8
Total	200	100.0

Most of the farmers (~61%) cultivated their lands four times during the season while ~23% cultivated two times whereas very little percent will cultivate 2 or 3 times in the season (Table 4).

Table 4. Respondents reporting the continuously cultivation period

Items	Frequency	Percent
Five seasons	18	8.9
Four seasons	121	61.6
Three seasons	14	5.8
Two seasons	47	23.7
Total	200	100.0

Sorghum (*Sorghum bicolo*r) was shown to be the main crop cultivated (47.7%), followed by sesame (*Sesamumindicum*) (38.7%), groundnuts (5.8%), and millet (*Pennisetum americanum*) (8.1%) as expressed by the respondents (Table 5). ~ 63.2% cultivated these crops for commercial purposes, while 36.8% cultivated crops for subsistence (Table 6).

Table 5: Main crops cultivated

Item	Frequency	Percent
Sorghum	93	47.4
millet (dukhen)	17	8.1
Sesame	77	38.7
Groundnuts	13	5.8
Total	200	100.0

Table 6: Main objectives of cultivating crops

Item	Frequency	Percent
Commercial	127	63.2
Subsistence	73	36.8
Total	200	100.0

Farmers use early maturing and drought tolerant seeds distributed to them by the FAO. Early sowing was done in May and June just before the rainy season to make benefit of the early rains, and to give chances to repeat sowing in case the first seed growth failed. Large quantities of seeds per hole was done to increase the density of plants per hole to reduce the possibility of seeds been blown by wind and losses by pests. If large quantities of seedlings germinate especially millet (dukhun) and sorghum (Dura) farmers resolve to what is known as shalikh that is pulling some seedlings after 15 days of germination in order to reduce competition for water and nutrients. Mulching was done by some farmers by leaving some stalks to cover the farm fields to maintain soil moisture. Small scale farmers use underground pits locally known matmuras. The capacity of the pits varied from 2 to 10 tonnes, Medium and large scale farmers use large pits up till more than 50 tonnes as secure for next season. Farmers showed indigenous knowledge of what is known as '*Traditional Divisions of Lunar*' that enables them of forecasting rainfall and hence can prepare to adapt to drought conditions.

DISCUSSION

Impact of Climate Change on Crop Production

The Standardized Precipitation Index (SPI) was used to detect drought which affect changes in areas of crop production (areas cultivated, areas harvested and the grain yields) for the years 1971-2010. The drought index showed that there was moderate to extreme drought events during the period 1972- 2008. There was evidence that the length of the growing season also became shorter (less than two months), with drastic changes in both rainfall amount and distribution during 1972 – 2008. Same observations were obtained for AD-Damsin for the years 1972 – 2008. It was shown that the cultivated areas decreased from the years 1973 to 2000, increased during the year 2010 then dropped to a very level during the year 2011. Agriculture is now limited for subsistence food crops like (millet –Dura and groundnuts) or cash crops (Dura–sunflower). Sorghum, sesame and groundnuts are the main crops cultivated in dry land farms.

Furthermore, Areima model predicted crop production through the years (2012-2018), showed that sorghum, millet, and sesame production with various degrees. Similar results were obtained by the studies of Crop Production and Food Security Assessment (CFSAM) conducted jointly by FAO and the Government of National Unity.

Adaptation to Climate Change

The onset of the rainy season is the most important variable for agricultural management (Stewart, 1991; Ingram *et al*., 2002; Ziervogel and Calder, 2003). It directly affects farming management practices, especially planting which, in turn, significantly affect crop yield and the probability of agricultural droughts (Kumar, 1998). In this respect, farmers in this study showed various coping mechanisms to ensure crop success and yield, this was shown by carrying out various practices such as using early maturing and drought tolerant seeds, early sowing, large quantities of seeds per hole to increase the density of plants per hole to reduce the possibility of seeds been blown by wind and losses by pests. Farmers also resolve to pull some seedlings after 15 days of germination in order to reduce competition for water and nutrients. Mulching was done by leaving some stalks to cover the farm fields to maintain soil moisture.

CONCLUSION

Use underground pits for storage of seeds. They showed indigenous knowledge of what is known as '*Traditional Divisions of Lunar*' that enables them of forecasting rainfall and hence can prepare to adapt to drought conditions. Similarly, it was shown that farmers possess valuable indigenous adaptation strategies that include early warning systems and recognize and respond to changes in climate parameters for example by maintaining flexible strategies with short and long cycle crop varieties.

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