Changing Climate and Farming Productivity in the Drylands of Eastern Sudan

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Abstract
This study analyzed and discussed the impacts of changes in incidence frequencies in rainfall and temperature on the productivity of dryland farming systems in Gadaref State, Sudan, during two periods (1943-1978 and 1979-2009). The results indicated an increase in the frequencies of maximum temperatures recorded within the ranges in the upper 30 and 40°C during the period 1979-2009. In contrast, recorded incidences of the maximum temperatures within the ranges in lower 30 and upper 20°C increased throughout the period 1943-1978. The same period 1943-1978 had more incidences of 20°C than those of the period 1979-2009. Recent years have hotter days and warmer nights than earlier ones. The occurrence of showers in the range 15-40 mm decreased in recent years, while those equal or less than 5 mm increased, especially in the months of August and September. There was a steady decline in the yields of crops per unit area, accompanied by a steady increase in the total grown area.

Keywords: temperature frequency, rainfall frequency, sorghum, sesame

Introduction
Africa is the most vulnerable to climate variability and change. The Sub-Saharan semi-arid zone in Africa, with annual rainfall varying from 100–200 mm in the North to 600–700 mm in the South (Nicholson, 1978), has a long history of climatic drought stress events. Droughts are understood as part of the normal climatic pattern in arid and semi-arid regions (Glantz, 1987). The irregular alternating patterns of wet and dry periods in the semi-arid zone on annual and decadal timescales are typical indicators for high climate variability. In this context, the droughts that affected the Sahel in the late 1960s through the 1980s and resulted in devastating famines, particularly during the 1970s, were extraordinary in the region in this century (Hulme, 2001). Extended dry spells and hot spells may be more prevalent in this region under climate change, putting rainfed agriculture systems at risk (Huntingford et al. 2005). However, some researchers showed that the climate of this region in late 1990s and early this century seems to have recovered (Brooks, 2004; Nicholson, 2005). Along this prospective, the scientists and practitioners always raise the question to what extend the climate is changing and how severe its impacts on the agricultural systems (Eltayeb, 1985). This study presented the changes in temperature and rainfall incidence frequencies and its impacts on the productivity of rainfed agriculture system in Gedaref state area, eastern Sudan.

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Methodology

Study area: Gedarif State is located in the eastern part of the Sudan (Fig. 1). It lies between longitudes 33-36°E and latitudes 14-16°N with an area of approximately 78,000 km². According to 1993 population census data, about one million inhabitants live in Gadarif State. About 90% population of Gedarif are farmer. The average population density was estimated at 10 people per square kilometer. Based on rainfall amount and main agricultural characteristics the area is divided into three main agro-ecological zones. The southern zone with highest rainfall ranging from 600 to 900 mm, the central zone with medium rainfall about 500-600 mm, and northern zone with very little rain fall <500 mm. The Gedarif produces 17 and 30% of total sesame and sorghum production in Sudan, respectively, with significant impact on the food security of the country.

Fig. 1: Location of Study area (Gedarif State).

Data and Analysis: Four months, June, July, August, and September (JJAS) daily maximum, minimum temperatures and rainfall data for Gedarif State was obtained from SMA (the Sudan Meteorological Authority) for the period 1943 to 2009. The missing data in the data set were checked and Hennessy et al. (1999) assumption was considered to accept any particular year if it had less than 10% of days missing and less than five consecutive days missing. Missing daily data in the present study were found in June and September 1952 for the maximum temperature and in June 1996 for the minimum temperature, which is around 2.8% for each individual month in the data set. A simple statistical frequency analysis was performed for the temperatures and rainfall data sets. The data records were treated into 3 sets: the whole period 1943 to 2009 as a base line, from 1943 to 1978, and from 1979 to 2009. The average, lowest and the highest value ever recorded in the data sets, were calculated for the 3 sets for comparison. The software used for this analysis was Microsoft Excel.
Results and Discussion

Fig. 2 shows the differences between frequencies of temperature incidences recorded for the two data sets (1943-1978 and 1979-2009). The frequencies differences were calculated by subtracting the frequencies of the period 1943-1978 from those of the period 1979-2009 at the same range of temperature. The results indicated an increase in the frequencies of maximum temperatures recorded within the ranges in the upper 30s and 40s°C (Figure 2-A) during the period 1979-2009. In contrast, recorded incidences of the minimum temperatures within the ranges in lower 30s and upper 20s°C increased throughout the period 1943-1978 (Figure 2-B). The same period 1943-1978 had more incidences of 20s°C than those of the period 1979-2009. These results clearly indicated that the recent years have hotter days and warmer nights than those of the earlier years.

![Fig. 2: Differences of daily temperature frequency incidences in the period 1979-2009 minus those in the period 1943-1978. (A) Maximum and (B) Minimum.](image)

Rainfall frequencies were treated similarly for the two sets of the years (1943-1978 and 1979-2009). The occurrence of showers equal or less than 5 mm increased in the recent period (1979-2009), especially in the months of August and September (Fig. 3). The analysis showed that the most frequent rainfalls in June-July-August-September season were in the range 15-40 mm. However, the incidences in this range clearly showed a decrease in the recent period (1979-2009). Due to the nature of the vertisols (heavy clay) in Gedarif area, too little (less than 10 mm) or too much (more than 60 mm) rainfall in a short storm are not favored. Too little rainfall is not enough to fill the cracks of the dry vertisols (Bronswijk, 1988) or to meet the demand of the crops under the semi arid hot conditions. On the other hand, too much rainfall in one storm would cause a runoff and waterlogging; both would results in crop damage in the field. Moreover, it is important the sensitivity of crops to drought and periods of heat.
stress at particular stages of development. This should raise an imperative question for research on the thresholds above which crops become highly vulnerable to climate and weather (Challinor et al., 2005; Porter and Semenov, 2005).

Fig. 3: Differences of daily rainfall frequency incidences in the period 1979-2009 minus those in the period 1943-1978.

Crop production is predicted to decline across the tropics and subtropics even under moderate climate change (Fischer et al. 2005; Parry et al., 2005). This is in agreement with the yields of rainfed crop production in the Gedarif area. Figure 4 shows a steady decline in the yields of the crops per unit area, while a steady increase in the total grown area. The compensation measure for the decreasing productivity is to increase the cultivated area. Climate variability plays an important role in determining productivity in the semiarid rainfed agriculture. However, management, farming and agronomic practices have a remarkable function in the productivity of the rainfed agriculture (Farah et al. 1996). Another serious point to raise is that the increase in the cultivated land would be at the expenses of the forestland (Ali-Babiker and Bongo, 2009). This supports the emerging evidences that major land use changes have already had detrimental effects on the local climate (Betts, 2005). To improve crop-climate prediction, more attentions need to be given to sub-seasonal effects of variability in climate and the impacts of weather thresholds on rainfed agriculture; both factors are likely to result in further reduction in crop yields. Moreover, the research and scientific community should pay special attentiveness to press forward on research for climate smart farming management practices and climate smart technologies.
Fig. 4: Productivity (A) and total area (B) of sorghum and sesame in Gedarif area during the period 1979-2009.

In conclusion, this study showed that climate change was evidenced through the increase of high temperature incidences in Gedarif area and the clear reduction in the incidences of the optimum rainfall storms during the June-July-August-September rainy season. Decisions for climate smart farming practices and technologies are deemed necessary to offset the negative impacts of the climate change on the productivity of dry rainfed farming under semiarid conditions.

References


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