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Socio-economic and Environmental Impact of Climate Change in the Gum Belt of North Kordofan, Sudan

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Abstract

The broad objective of this research is to study the socio-economic impact of climate change in the gum Arabic belt of North Kordofan state. Moreover the research is intended to investigate farmers' perception on climate change and variability, identify indicators of climate change and the consequences of climate change on production systems. The primary data was collected through face-to-face interview with 140 farmers, group discussions with key informants, and observations. A random sample of respondents was selected from six villages in Bara locality. The data were analyzed using descriptive statistics and t-test, normalized rain fall and temperature anomalies analysis. The main findings of the research are the indicators of climate change as perceived by the respondents; frequent drought cycles (99.3%), erratic nature of rains (91%), dust storms (74.1%), increase of temperature (67%), and an increase of wind speed (63.6%). These indicators are consistent with the analysis of meteorological data. T-test analysis for crop productivity before ten years and the last year (2015) revealed significant reduction at ($p > 0.05$) in the yield of the agricultural crops (Millet, sorghum, sesame, and Roselle). T-test analysis for the last year (2015) and before ten years indicated a significant decline at ($p>0.05$) for; areas of *A. senegal* gardens, *A. senegal* stocking density, gum production and income from gum Arabic. The impacts of climate change on livestock are represented in deterioration of range lands (80.7%), animal mortality (72.9%) and changing of stock structure (2.1%). The main conclusion drawn from this study is that climate change is recognized as a challenge for the sustainable livelihood of local communities in the study area, and this necessitates the intervention of the different governmental institutions to enhance the locally driven adaption options of local communities.

Keywords

Climate Change, Farmer Perception, Gum Belt, North Kordofan

1. Introduction

Climate change is defined by United Nations Framework Convention on Climate Change (UNFCCC) as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and in addition to natural climate variability observed over comparable time period [34]. Climate change is, in many parts of the world, adversely affecting socio-economic sectors, which include water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health. Developing countries are the most vulnerable [35].

Sudan has a range of ecosystems and agricultural systems, throughout much of the country. Water resources are limited, soil fertility is low, and drought is common [25]. These underlying conditions are exacerbated by various human pressures. Climate change directly affects agricultural production, as agriculture is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impacts of global climate change [27]. Climate change is considered as posing the greatest threat to agriculture production and food security in agriculture-based countries of Sub-Saharan Africa (SSA), due to their low capacity to effectively cope with a possible decrease in yields among others [29]; [26] The areas suitable for agriculture in SSA, particularly along the margins of semi-arid and arid areas are expected to decrease and, it would further affect food security and exacerbate malnutrition in the region [9]. Climate changes are likely to disrupt animal communities; potentially uncoupling predator-prey and competitive interactions between species and ultimately influencing community composition, including migratory species are particularly vulnerable since a discrepancy could develop between the timing of migration and the availability of food. Hence the structure, functioning of ecosystems and mechanisms of heat exchange between the animal and its surroundings could change [22] [28].

Drought is one of the most important climate phenomena that the country faces as recurring series of dry years have become in continuous occurrence in the Sudano-Sahel region. Drought threatens approximately 12 million hectares of rain fed land, particularly in Northern Kordofan and Darfur states [36]. The ecologically adapted Agro-silvo-pastoral systems and practices of land use existing in North Kordofan State are under severe stress by the rapid socio-economic changes; population pressure accompanied with over-exploitation of forest resources, over-cultivation of both cash and food crops, in addition to over-grazing, which have negative impacts in terms of resource degradation [15].

The recent droughts have affected the gum gardens of Northern Kordofan and led to the breakdown of the gum Acacia agro-forestry system, reduced gum production and threatened the stability of the agricultural soils [19]; [12] and [24]. During the last three decades, North Kordofan has experienced catastrophic and frequent droughts with far-reaching consequences on agricultural and pastoral systems, regional economy, traditional family livelihood and environment [18]. The situation is complicated by erratic and unevenly distributed rainfall, which is considered as one of the most serious challenges facing the state [11] The aim of this research is to study the socio-economic and environmental impacts of climate change, investigate farmers' perception on climate change and climate variability and identify the indicators of climate change in North Kordofan State

2. Materials and Methods

2.1. Study Area

The study was conducted in the year 2015 in Bara Locality which is a part of the gum belt in Sudan. It lies between latitudes 13° 34¯ and 14° 47 ¯ N and longitudes 30° 5¯ and 31° 47¯ E figure 1 with an area of 11850 Km² and it is about 56 km North of Elobeid town [11].

2.2. Data Collection

The primary data were collected through face-to-face interview with farmers, group discussions with key informants, and observations. A random sample of 140 respondents was selected from six villages in Bara locality for this research using multiple stage random sampling. The tool of data collection for social survey is the questionnaire which was constructed following the scientific measures to collect information from the local people in the selected villages. Secondary data (temperature and rainfall over the last three decades) were obtained from Bara Metrological Station.

2.3. Data Analysis

The data from social survey were analyzed using descriptive statistics, and t-test. The meteorological (Rainfall and Temperature) data were analyzed using normalized rain fall and temperature anomalies analysis.
as:

$$\mathrm{RAij} = \frac{(\mathrm{Pt} - \mathrm{Pm})}{\sigma}$$

Where: RA_{ij} is the normalized rainfall total for station i during a year (or season) j; P_t the annual rainfall in year t; P_m the long-term mean annual rainfall over the period of observation; σ the S.D. of annual rainfall.

Figure 1. *Location of the study area.*

3. Result and Discussion

3.1. Indicators of Climate Change in the Study Area

The result shows the main indicators of climate change and variability as perceived by the local people (Figure 1). Ninety one per cent of the interviewed sample asserted that fluctuation of rainfall in terms of intensity and distribution compared with the history of the study area is a criterion of climate change. This agrees with [10] showing that projections of rainfall under climate change conditions shows sharp deviations from baseline expectations. Drought has become a regular visitor to the study area. Farmers always have nagging doubts whether there will be rains next season or not. This fact was supported by 99.3% of the respondents. Another indicator of climate change in the study area, as perceived by the local people, is the sharp increase of temperature as indicated by 67% of the respondents. Heat has negative impact on crop productivity and animal rearing as supported by [9] who reported that an increased temperature of 1-2°C may have a negative impact on crop growth and yield at low latitudes. This finding agrees with [7] showing that climate scenario analyses conducted as part of the preparation of Sudan's Firs National Communication Report indicate that average temperatures are expected to rise significantly relative to baseline expectations that the tempreature will increase. By 2060, projected tempreature increases from 1.5°C to 3.1°C during August to between 1.1°C to 2.1°C during the month of January [16].

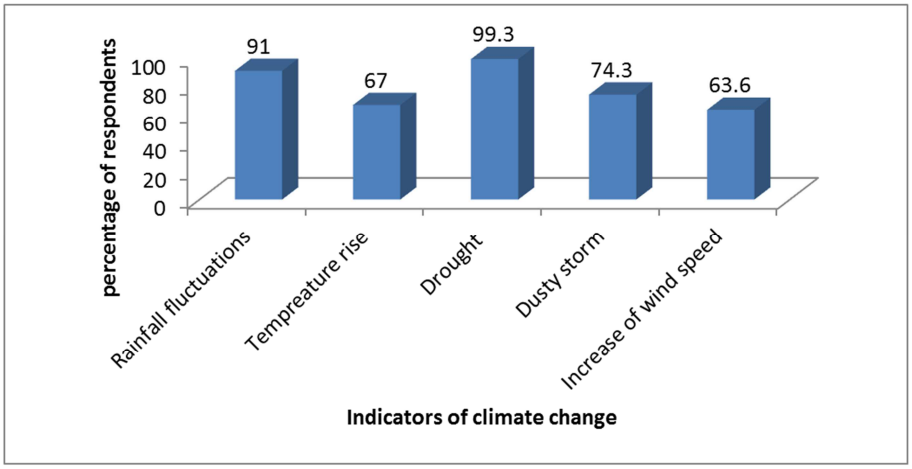


Figure 2. *Indicators of climate change in the study area.*

The evidence of temperature rise is further indicated by [9] and [30] who mentioned that climate change will increase drought and desertification as a consequence of less rainfall and increased extreme weather events. Other criteria of climate change and variability is represented in frequent dust storms and increase of wind velocity as indicated by 74.3% and 63.6% of respondents, respectively (Figure 2)

Consistent with farmer's response, the analysis of meteorological data over the last decades indicated high inter-annual and inter-seasonal variations, decreasing of rainfall amounts and increasing of temperature in the study area. Figure 3 and Figure 4 show the normalized annual rainfall and annual temperature anomalies and trends for the last three decades in the study area.

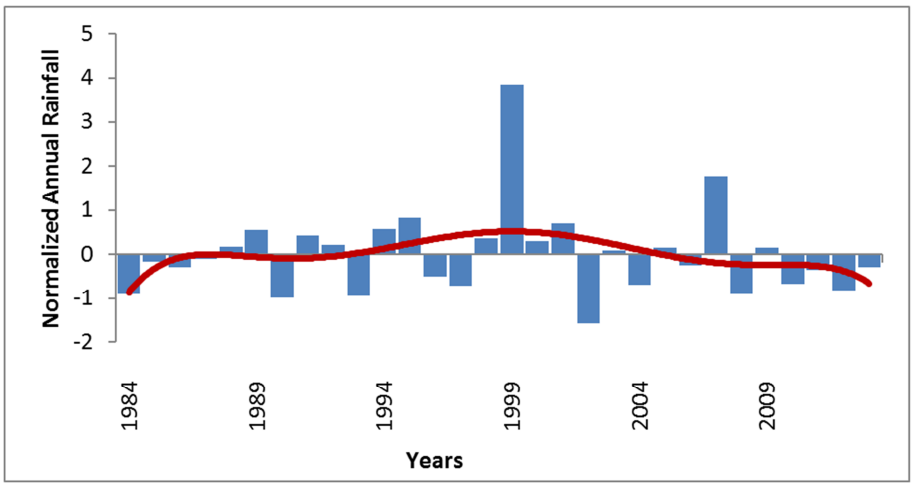
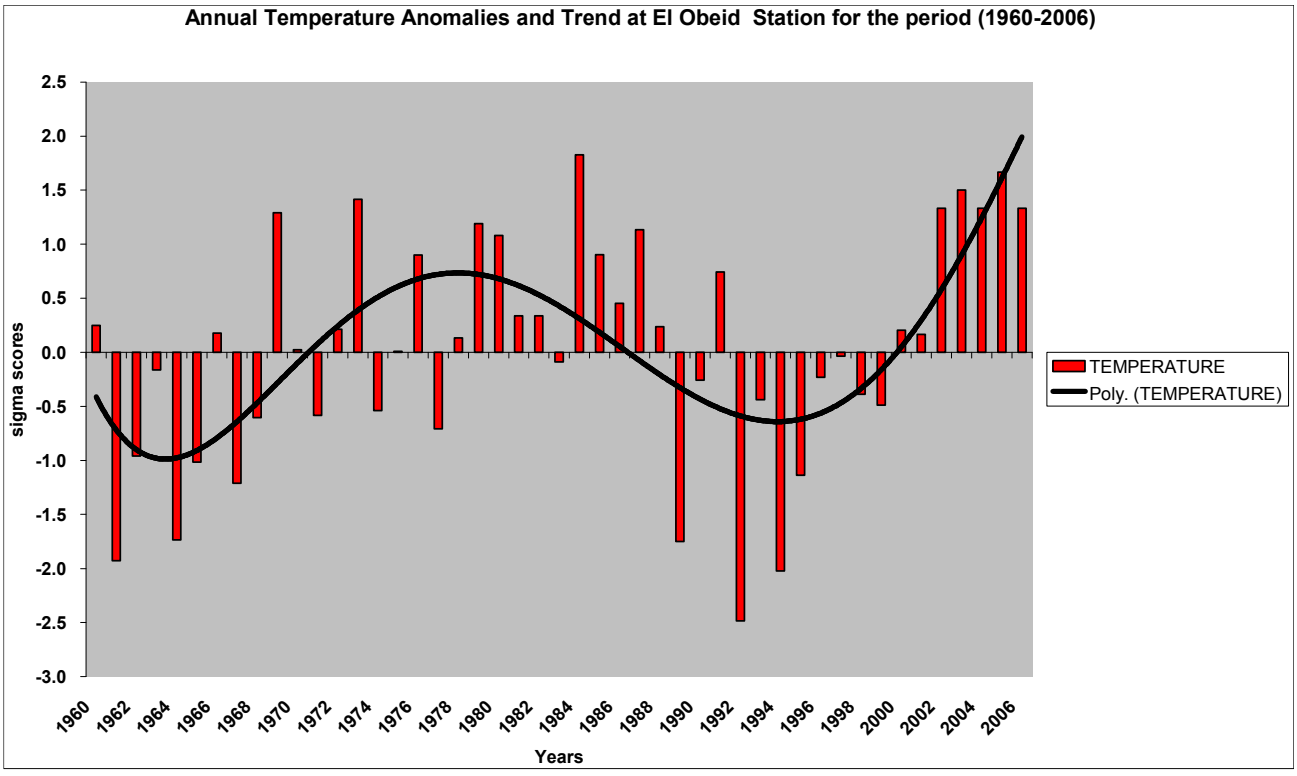


Figure 3. *Normalized annual rainfall for the last three decades (1984-2013) in the Study Area.*



Source: [7]

Figure 4. *Annual Temperature Anomalies and Trends in the study area for the period of (1960-2006).*

3.2. Impact of Climate Change on Crop Production in the Study Area

The T-test result for the production of main crops between this year (2015) and before 10 years showed that millet production decreased significantly ($p > 0.05$) in. Similar result, were obtained for sorghum, sesame and Roselle production which also decreased significantly ($p > 0.05$), Table 1.

Table 1. *Impact of climate change on crop production in the study area.*

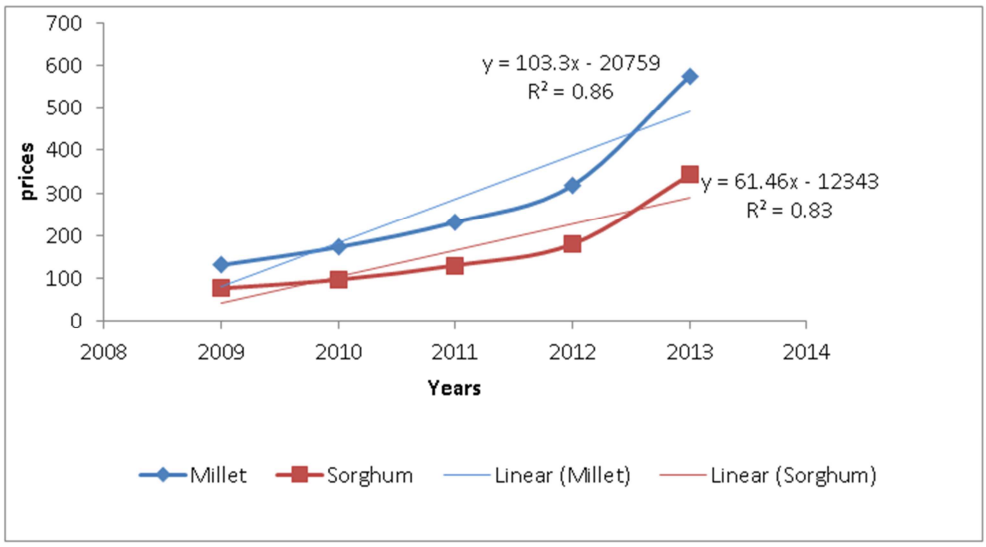
Item	Mean	Std. Deviation	d.f	t	P
Millet production Sacks/ Mukhamas before 10 years- Millet production Sacks/ Mukhamas this year (2015)	4.352	3.498	139	14.722	0.000
Sorghum production/ Mukhamas before 10 years- Sorghum production Sacks/ Mukhamas this year (2015)	1.563	2.461	139	7.515	0.000
sesamme production Sacks/ Mukhamas before 10 years- Sesamme production Sacks/ Mukhamas this year (2015)	3.0179	2.212	139	16.14	0.000
Rosalle production Sacks/ Mukhamas before 10 years- Rosalle production Sacks/ Mukhamas this year (2015)	0.888	1.046	139	10.057	0.000

In general the production of main food and cash crops in the study area was reduced due to climate change and variability at the study area as the people perceive. This result agrees with [32] who mentioned that the poor rainfall as one of main indicators of climate change is affected crop production and led to massive crop failure. This is also in line with [13] which indicated that sorghum and millet production in Northern Kordofan Region declined as the result of climate change by 92 and 86%, respectively, compared with the average of 1974-81.

3.3. Impact of Climate Change on Food Price and Food Access in the Study Area

The prices of main food crops increased in the study area mainly due to the sharp decline in the productivity of subsistent food crops under an ever changing climate. Figure 5 shows the impacts of climate change on the prices of agricultural crops.

The price of millet and sorghum in North Kordofan State increased and continued to increase since the sixties of the last centenary with R^2= (0.86) and R^2= (0.83) consequently. This can be attributed to the decline of rainfall during the same period of time. This is also supported by [14] who argued that the decline in cereal production led to rapid price increases of food crops. Accordingly, there is a severe decline in purchasing power of rural community. Also [36] mentioned that, in 2000, drought reduced food stocks and caused prices to raise three-folds compared to the same period in the previous year.



Source: Elobied crops market (2015)

Figure 5. *Impact of Climate Change on Food Price in the Study Area.*

Accordingly, climate change affected food access in the study area through its impact on food production and food price as mentioned by [6] that access to food is a function of production and prices.

3.4. Impact of Climate Change on *A. senegal* Gardens in the Study Area

The area of *A. senegal* gardens was reduced significantly at ($p>0.05$) in the study area, also the density of *A. senegal* in the gardens of respondents was reduced significantly ($p>0.05$). The same was true for gum production in the study area. The results revealed that there is significant decrease of gum production ($p > 0.05$) in the study area. The financial returns from marketing of gum Arabic in the study area also decreased significantly ($p > 0.05$) in the study area as shown in Table 2.

Table 2. *Impact of climate change on A. senegal garden in the study area.*

Items	Mean	Std. Deviation	d.f	t	P
Areas Gum Gardens/ Mukhamas before 10 years- areas gum garden/ Mukhamas this year (2015)	2.593	13.059	139	2.349	0.20
No. of *A. senegal* tress/ Mukhamas before 10 years- No. of *A. senegal* tress / Mukhamas This year (2015)	47.364	78.654	139	7.125	0.000
Gum productivity / Mukhamas before 10 years- Gum productivity/ *Mukhamas* this year (2015)	0.245	0.608	139	4.759	0.000
Return from gum in SDG before 10 years- Return from gum in SDG this year (2015)	7.143	45.901	139	1.842	0.068

The reduction of the number of *A. senegal* trees per *Mukhamas* in the study area coupled with shrinkage of the area cover by *A. senegal* led to reduction of gum production and consequently reduction of financial returns. This finding agrees with [3] and [31]. Who indicated that there were deteriorations of *A. senegal* garden and reduction of gum production between mid-seventies and mid-eighties. Also, [17] reported deterioration of the gum Garden from Bara, E1 Mazroub, and E1 Khuwei and up to E1 obeid. Also, [20] and [2] reported that the percentage of *A. senegal* trees in Bara had decreased from 31% in 1995 to 2% in 2008 and has a lowest density in comparison with *Acacia tortilis* and *Leptodenia pyrotechnica*.

3.5. Impact of Climate Change on Livestock in the Study Area

North Kordofan State lands are poor for cultivation and suitable for grazing. Sheep and goats are successfully reared in this tough land, with some camels. Cattle are few due to ecological and topographical feature [1]. The plant diversity varies and the vegetation density increases southwards. The distribution and condition of natural vegetation is mainly a function of rainfall amount and distribution. Seasonal water courses "khors" and local topography also play an important role in the non-uniform pattern of distribution. The vegetation cover is a mixture of grasses and herbaceous plants intermingled with Acacia trees and shrubs. Climate change together with land mismanagement have contributed to the condition that almost more than 50% of the North Kordofan State has lost its valuable herbs. Table 3 shows the impacts of climate change and variability on rangelands and animal production.

Table 3. *Impact of climate change on live stock in the study area.*

Impact	Percent	Mean	Std. Deviation
Animal mortality	72.9	1.27	0.446
Disease	72.1	1.28	0.450
Deterioration of range lands	80.7	1.19	0.396
Invasion of unpalatable and toxic grasses	2.9	1.97	0.167
Crossing devastating area	21.4	1.79	0.412
Changing of stock structure	2.1	1.98	0.145
Natural resource base conflict	0.7	1.99	0.085

The majority of respondents (80.7%) indicated deterioration of range lands conditions and structure in the study area where many palatable species lost their dominance for less preferred species and new invaders colonized most, if not all, of the natural rangelands. This result agrees with [5] who reported that, the changes in grass availability and quality, which affect animal production through changes in feed supplies. Regarding range plants diversity, the perception of community members interviewed is that the present situation is worse and in relation to the degree of affection of the different valuable range plants as decreasing while the less prefer species as increasing. About 72.9% of the respondents stated that the impact of climate change on animal is the increase of animal mortalities, while 72.1%mentioned spread of epidemic diseases as the main factor that impacted the rangelands and animal production in the study area. This agrees with [33] which showed that pastoralist across the Sudan has been affected by natural disasters like climate change, with dramatic consequences on animal populations through diseases and mortality. The main epidemic diseases that represent a problem to the local people are; small box, conteques bovenie pleero pneumoing and anthrax fever as indicated by 29.3, 44.3 and 35% of respondents, respectively. This result agrees with [33] which indicated, climate change was affected animal health. Also, [21]; [23] and [4] reported that warming temperatures will likely expand the range of important vector-borne diseases. The respondents in the study area were able to mention other impacts attributed directly or indirectly to climate change like invasion of unpalatable and toxic grasses, crossing devastating area and changing of stock structure with 2.9%, 21.4% and 2.1%, respectively. This result is in line with [28] who reported that climate changes are likely to disrupt animal flocks and ultimately influencing community composition and structure.

4. Conclusions

Climate change in the study area has expressed itself in term of frequent drought cycles, erratic nature of rains, dust storms, increase of temperature and increase of wind speed. The present situation of the environment is an outcome of the

impacts of climate change where all the sectors particularly water resources; agriculture and health were affected by such events which led to changes in the livelihood. The main impacts of climate change in the study area are; decline in the productivity of main agricultural crops, where millet production per *mukhamas* in showed significant variation at ($p>0.05$), and the same is true for Sorghum, Sesame and Roselle. Climate change and variability also resulted in negative impacts on the prices of main food and cash under ever changing climate. Where prices of millet and sorghum increased and continue to increase since the sixties of the last century. The area of *A. senegal* gardens was also reduced significantly at ($p > 0.05$) in the study area, and the density of *A. senegal* in the gum gardens was reduced significantly ($p>0.05$). The same is true for gum production in the study area. The results revealed that there is significant decrease of gum production at ($p > 0.05$) in the study area. Impacts of climate change on livestock sector is represented in sharp increase of animal mortality, prevailance of diseases, deterioration of rangelands, disappearance of palatable species, change of livestock structure, conflicts and invasion of less prefered species.

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