Adaptation Strategies to Climate Change in the Gum Arabic Belt of North Kordofan, Sudan

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ABSTRACT

Climate change will, in many parts of the world, adversely affect socio-economic sectors, which include water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health, developing countries are the most vulnerable. 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 the climate change studies in Sudan are not well – known to a lot of people. The main objective of this paper was to investigate the climate change adaptation strategies adopted by local communities in the gum Arabic belt of North Kordofan State (Bara Locality). It tried to examine the impact of the climate change on agricultural production and securing food supply. The primary data was collected through face-to-face interview with local people, group discussion with key informants, and personal observations. A number of 140 respondents were selected among 697 household from six villages in Bara Locality using multiple stage random sampling. The data were analyzed using descriptive statistics, t-test and logistic regression. The main findings of the study showed that the adaptation strategies for improving crop production were, using improved seeds (43.6%), crop rotation (42.1%), fallow period (81.4%) and early planting (1.4%). The adaptation strategies for food security and poverty reduction were, reducing meals (15%), using alternative food (95%), plantation of *Hyphenetheibica* (11.4%) and fisheries (40%). The adaptation strategies for livestock production and rangeland management were, using alternative feed (94.3%), fences (35%), changing animal type (26.4%) and grass seed broadcasting to enrich the range (39.3%). The adaptation strategies for forestry and natural resource conservation were, expansion of *A. senegal* plantations (42.9%), establishment of gum Arabic production associations (18.6%), shelterbelts (40%), energy alternatives (40.7%), change of traditional houses (74.3%) and adoption of communal forests (10%). The results from logistic regression model revealed that household socio-economic factors were the main determining factors that influencing farmer' choice and adaptation strategies. The main conclusion drawn from this study is, climate change is recognized as a real challenge for the sustainable livelihood of local communities in the study area,

and the adaptation strategies taken by the local inhabitants are not enough to face such change. This necessitates the intervention of the different governmental institutions to enhance the locally driven adaptation options by local communities enforce a newline.

Keywords: Climate change, Adaption strategies, Food security, Gum belt, North Kordofan

1. Introduction

Climate change was 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 which is in addition to natural climate variability observed over comparable time period (UNFCCC, 1992). In Sub-Saharan African countries land use is dramatically affected by the consequences of climate change. This is the observation by the international scientific community and also the concern of global conventions like UNFCCC (Boko *et. al.,* 2007, Bryan *et. al.,* 2009). Extreme events in Sudan have already increased in the last 20 years (Fadel-El Moula, 2005). Climate change is also projected to reduce average rainfall by about 6mm per month during the rainy season. Such changes in temperature and precipitation are likely to undermine the development progress that is occurring in many sectors in Sudan. Most land in Sudan is quite sensitive to changes in temperature and precipitation. Food security is mainly determined by rainfall, with more than 70% of Sudan's people directly dependent on climate sensitive resources for their livelihoods. Forested areas have already been degraded, with forest cover falling from between 36 to 43% of the country's total area in 1958, to 19% in 1990 (Adam and Abdalla, 2007).

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 (NBSAP, 2004). These underlying conditions are exacerbated by various human pressures. Drought is one of the most important climate phenomena that the country faces, as a recurring series of dry years has become a normal occurrence in the Sudano-Sahel region

The 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 (IFPRI, 2007). The recent droughts had affected the gum gardens of Northern Kordofan state and

led to the breakdown of the gum Acacia agro-forestry system, reduced gum production and threatened the stability of the agricultural soils (Khalid, 1985).

The local people learn from past events and current situations about the frequency and the likely consequences of various shocks (Deressa et al. 2011). Thus, the local people tend to reshape their livelihood systems to buffer against potential catastrophic events. They prepare themselves with all means at their disposal and with any external opportunity available (Thornton et al. 2010; Alebachew and Ayenew 2011and Regassa 2011).

Studies indicate that farmers do perceive that climate is changing and taking adaptive mesures to reduce the negative impacts of climate change (Maddison, 2006; David *et. al*., 2007; Ishaya and Abaje, 2008; Hassan and Nhemachena, 2008; Semenza *et. al.*, 2008; Akter and Bennett, 2009; Sampei and Aoyagi-Usui, 2009; Mertz *et. al.*, 2009).

Traditional knowledge can help to provide efficient, appropriate and time-tested ways of advising and enabling adaptation to climate change in communities who are feeling the effects of climate changes (UNFCCC, 2007). The interaction of multiple stresses- endemic poverty, ecosystem degradation, complex disasters and conflicts, and limited access to capital, markets, infrastructure and technology- have all weakened people's ability to adapt to changes in climate (Zakieldeen, 2007).

1.1 The objective of the study

The main objective of this paper is to investigate the climate change adaptation strategies adopted by local communities in the gum Arabic belt of North Kordofan State (Bara Locality).

The specific objectives are to:

1. Examine the impact of the climate change on agricultural production and securing food supply.
2. Investigate the climate change adaptation strategies adopted by local communities in the gum Arabic belt of North Kordofan
3. Determine of the choice and adoption of climate change adaptation strategies

2. Materials and methods

The study was conducted 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 with an area of 11850 Km² and it is about 56 km North of Elobeid town (Hano, 2003). Figure (1).

The primary data was collected through face-to-face interview with local people, group discussion with key informants, and personal observations. A number of 140 respondents were selected among 697 household from six villages in Bara Locality using multiple stage random sampling technique. The data were analyzed using descriptive statistics, t-test and logistic regression.

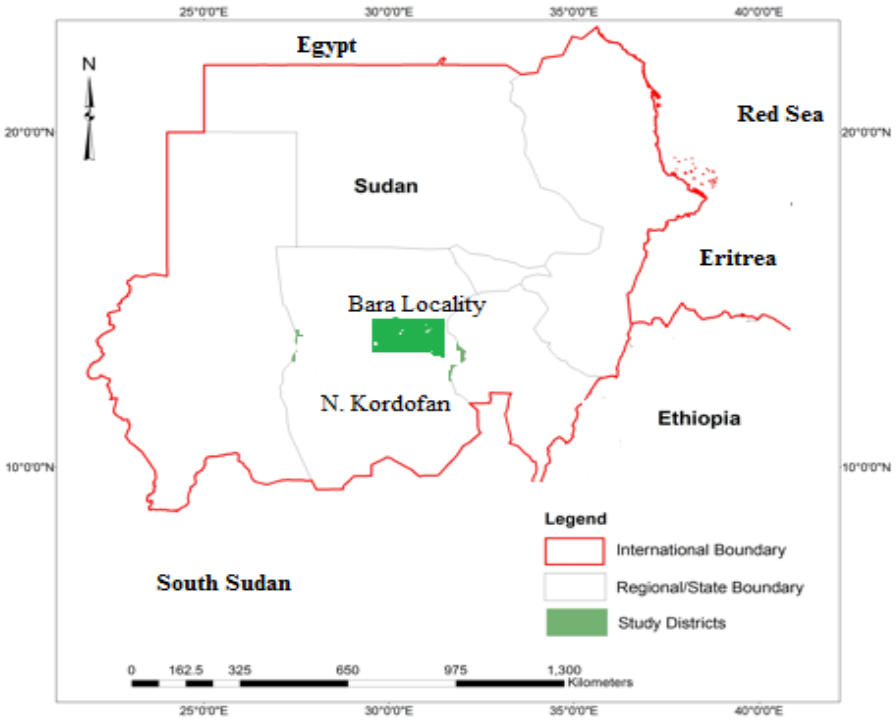

Figure 1: Map of the Study Area

3. Results and Discussion

3.1 Impact of climate change on Agricultural production

Fluctuation of rainfall, frequent drought cycles, dust storms and winds has direct impact on the productivity of agricultural crops in the state and has negative impact on the growth and development of agricultural crops. Figure (2) shows the impacts of climate change, as perceived by the respondents.

The entire interviewed sample (100%) asserted that crop production is directly associated with the intensity and distribution of rainfall in the study area. When rains are abundant, satisfactorily production is obtained and vise versa. This agrees with Parry *et. al.*, (1999) who mentioned that 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. Moreover, variability in rainfall has an arguably more significant impact on

livelihoods, particularly in terms of the frequency of drought. The Sahelian band between 11 and 17 degrees north has a particularly variable rainfall. The effect of this is evident in the variability of the vegetation and crop productivity. The annual maximum vegetation (measured in NDVI) has a variability of over 30% in parts of the Sahel and less than 10% away from this area (Tearfund, 2007). Furthermore, records from El Fasher indicate that the frequency of drought has increased since the early 1970s, with 16 of the 20 driest years on record occurring since 1971 (Tearfund, 2007b). This increase in frequency of drought is consistent with general patterns of climate change, in which increasing variability is a leading impact.

About 38.6% of the respondents accentuated that pest infestation could be considered as a challenge due to climate change, as perceived by the local people. Since the developing seedlings of agricultural crops are not healthy due to drought and lack of supplementary irrigation. This situation enhances the process of destruction of the agricultural crops by pest. The rest of the respondents believed that one of the most important impacts of climate change is represented in the deterioration of soil conditions (physical and chemical) which lead to the loss of soil fertility.

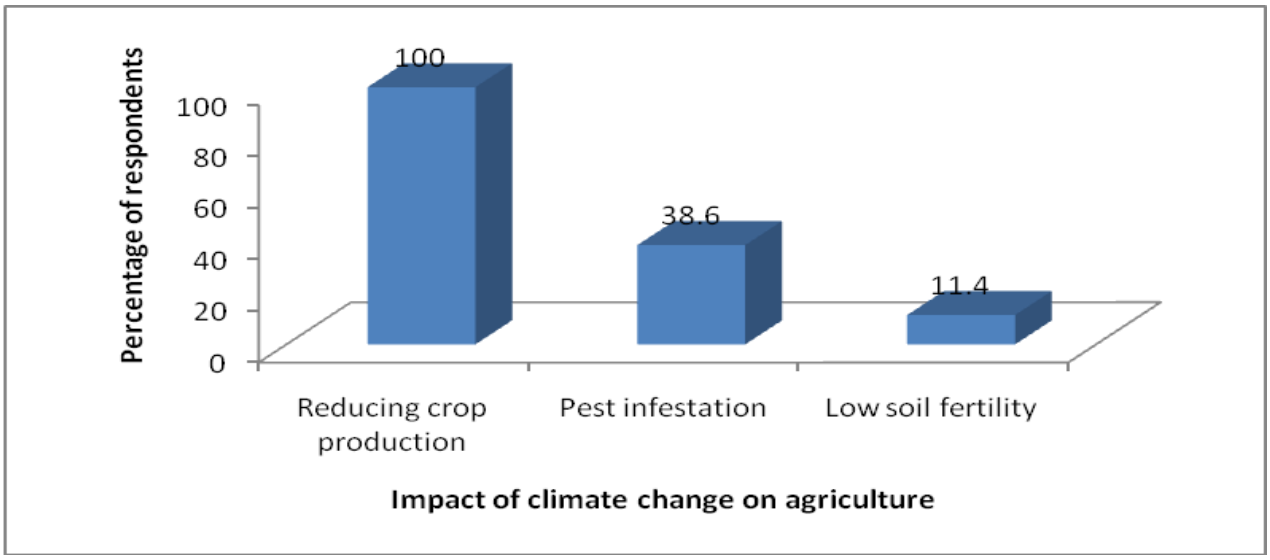

Figure 2: Impact of Climate change on agriculture

3.2 Impact of climate change on food availability

Generally, the entire interviewed sample in the study area asserted that crop production is always lagging far behind expectation, and farmers always dream of good agricultural season next year. In the past farmers harvest satisfactory production some of which is stored at traditional storage facilities (matmooura and sweepa) and the surplus is disposed off to the village markets. Now all

the respondents indicated that the produced quantities of food crops are not enough for domestic consumption. Table (1) shows the produced, consumed and amount of food deficit.

There is a deficit of about 6.26 sacks for local consumption last year in the study area.
Thus, climate change affects food availability as well as food security. This result agrees with (FAO, 2000) and (Thomton *et. al.*, 2010) who clarified that food availability is the result of food production and distribution, the comparison of available food to the estimated domestic consumption gives estimation to the deficit of food availability were the channel which climate change directly affects food security

Table 1: Produced food, consumed food and amount of food deficit per sacks in the study area last year

Villages	Quantity produced in sacks	Quantity consumed in sacks	Amount of deficit in sacks
Greigikh	0.85	2.14	1.29
Umdaioga	2.85	2.53	0.32
Eyal Ali	0	4.42	4.42
Sheg elnom	0.66	2.26	1.6
Foga	1	3.35	2.35
Umdabos	0	3.66	3.66
Total	0.35	6.54	6.26

Source: depicted from on data, 2014

3.3 Impact of climate change on food price and food access

The prices of main food and cash crops increased in the study area mainly due to the sharp decline in the productivity of subsistent and cash crops under an ever changing climate. Figure (3) 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 century. This can be attributed to the decline of rainfall during the same period of time. This is also supported by Ibrahim (1984) 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 Zakieldeen (2007) mentioned that, in 2000, drought reduced food stocks and caused prices to raise three-folds compared to the same period in the previous year. Accordingly, climate change affected food access in the study area through its impact on food production and food price as mentioned by (Ericksen *et. al.*, 2011) that access to food is a function of production and prices

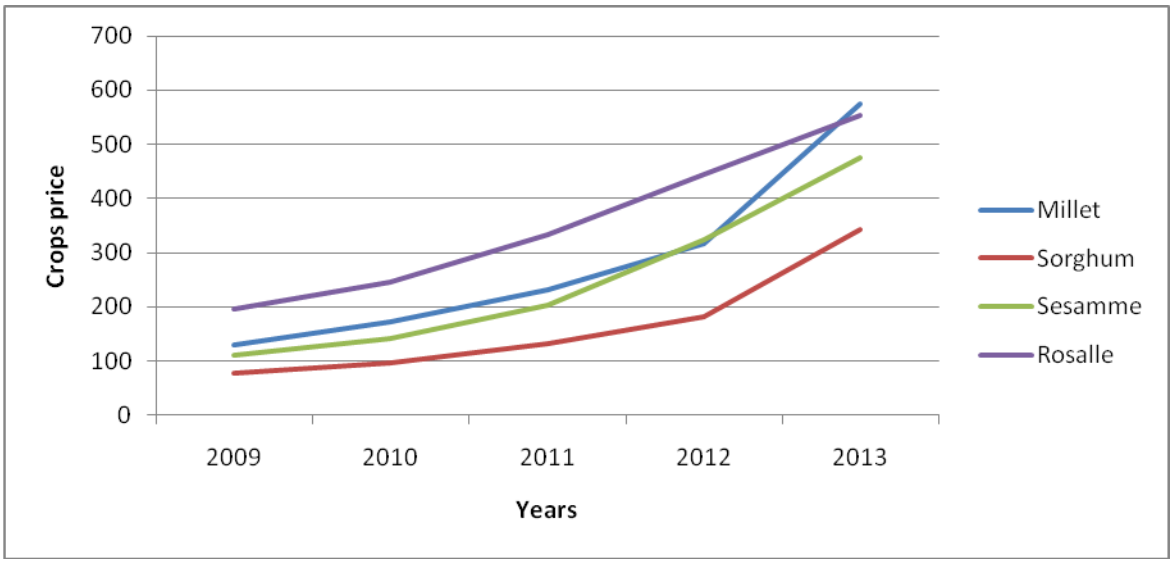

Figure 3: Impact of climate change on food price

3.4 Adaptation strategies adopted by local farmers in the study area

3.4.1 Adaptation strategies for crop production

The results showed the adaptation strategies adopted by local farmers in order to cope with the reduction of crop production in the study area, table (2).

Table 2: **Adaptation strategies for crop production**

Adaptation strategy	Frequency	Percentage
Using improved seeds	61	43.6
Crop rotation	59	42.1
Fallow period	114	81.4
Early planting	2	1.4

Source: depicted from on data, 2014

Different adaptation strategies adopted by local people in order to cope with reduction of crop production as a result of climate impacts. Using improved seed, which have a short production cycle, early maturing, and drought resistant variety. Crop rotation for diversifying the crops and efficient use of minerals in the farm land. Fallow periods, for restoring minerals in the farm land. Early planting, in order to use all amount of rain fall from the onset of rainfall tell the end of rainy season.

3.4.2 Adaptation strategies for Food security and poverty reduction

The results expressed the adaptation strategies adopted by local farmers for Food security and poverty reduction in the study area, table (3).

Table 3: Adaptation strategies for food security and poverty reduction

Adaptation strategy	Frequency	Percentage
Buying food from market	139	99.3
Reducing of meals	21	15
Using alternative foods	133	95
Plantation of *Hyphenetheibica*	16	11.4
Fishing	56	40

Source: depicted from on data, 2014

Buying food from market, because the production of main food crops (millet and sorghum) is not enough to cover the domestic consumption, the people tend to buy from markets to fill the gap. Reducing of meals, because the production of main food crops is not enough to cover the domestic consumption and the purchasing power is low, then people tend to reduce the number of meals per day. Using alternative foods, they use other food staff rather than millet and sorghum. Plantation of *Hyphenetheibica*, the women in the study area use this tree species in making hand craft and sell it the market for income generation as strategy for poverty reduction. Fishing, as strategy for poverty reduction, after selling the fish the money back to the local community in the form of services.

3.4.3 Adaptation strategies for Livestock production and rangeland management

Different adaptation strategies adopted for Livestock production and rangeland management as showed in table 4.

Table 4: Adaptation strategies for livestock production and rangeland management

Adaptation strategy	Frequency	Percentage
Using alternative feed	132	94.3
Collection of grass residue	69	49.3
Enclosure	49	35
Changing animal type	37	26.4
Selling of animals	38	27.1
Grass seed broadcasting	55	39.3

Source: depicted from on data, 2014

Using alternative feed, like collection of crop residue after harvesting period in order to feed animal in the dry season. Collection of grass residue, during the rainy season, the local people collects the grass from the range land and conserves it for the dry season. Enclosure, protection of range land areas till the grasses compete its life cycle to produce seeds for natural regeneration for next season. Changing animal type, change of sheep's with goats, because goats are able to leave in hard condition. Selling of animals, in the drought periods when the range land was degraded and

the grass is not enough to feed the animal, the local sell part of animal to reduce the pressure on range lands. Grass seed broadcasting, through collection of grass seeds from the range lands that have well stock and distributed it in the degraded areas.

3.4.4 Adaptation strategies for Forestry& Natural resource conservation

The results find out the adaptation strategies for Forestry & Natural resource conservation in the study area, table 5.

Table 5: Adaptation strategies for Forestry& Natural resource conservation

Adaptation strategy	Frequency	Percentage
Plantation of *Acacia senegal* trees	60	42.9
Plantation for sand dune stabilization	56	40
Shelter belt	56	40
Community forestry	14	10
Alternative source of energy	57	40.7
Changing house pattern	104	74.3

Source: depicted from on data, 2014

Plantation of *Acacia senegal* trees, *Acacia senegal* is the main ingredient in the farming system where produce gum Arabic for cash income and fixing nitrogen in the soil for increasing soil fertility for crop production. Plantation for sand dune stabilization and Shelter belt, by planting of *Leptodenia pyrotechnica* and *Eucaleptus microtheca* to protect farm land and resident area from sand dunce movement and dusty storms. Community forestry, as demonstration field for training and capacity building and providing basic needs of local community. Alternative source of energy, by introducing gas to reduce use of charcoals and fules woods that collected from the forest areas. Changing house pattern, by adoption of mud for building house instead of poles as strategy of natural resource conservation.

3.5 Determinants of the choice and adoption of climate change adaptation strategies

3.5.1 Factors determining adoption of improved seed, crop rotation, fallow period and fisheries

In the study area, the factors that affect the adoption of certain adaptation strategies are displayed in table (6). The findings of the above table reveal that adoption of improved seeds (early maturing) is affected significantly by the availability and efficiency of extension services and gender ($p > 0.05$). This finding emphasizes the role of extension messages, if scientifically formulated, in changing the attitudes and perceptions of farmers and enhance the adoption of new innovations. The same is true for the gender issue; adoption of intervention is a gender sensitive

issue. This might be verified by the fact that women are normally suspicious about new interventions and avoid the risks of unknown results.

Table 6: Factors determining adoption of improved seed, crop rotation, fallow period and fisheries

Adaptation strategy / Factors	Improved seeds		Crop rotation		Fallow periods		Fisheries	
	β	Sig	β	Sig	β	Sig	β	Sig
HH age (yrs)	-0.021	0.641	0.003	0.940	-0.102	0.135	0.085	0.073
Family size (no)	0.030	0.867	-0.042	0.813	0.568	0.053	-0.151	0.433
Extension service	-0.896	0.017*	-0.880	0.016*	0.156	0.762	-1.164	0.005*
Education level (School yrs)	-0.038	0.403	-0.018	0.691	0.179	0.011*	-0.015	0.756
HH gender	-1.103	0.021*	-0.265	0.568	-0.377	0.562	-1.516	0.003*
Livestock (no)	-0.010	0.470	0.008	0.560	-0.028	0.228	-0.012	0.441
A. senegal area	-0.040	0.918	0.199	0.599	2.109	0.003*	-0.207	0.623
Constant	2.837	0.052	1.571	0.266	-3.231	0.106	0.006	0.997

*Significant at $\alpha = 0.05$; n =140 in all cases

Crop rotation is affected significantly by extension services at ($p > 0.05$), where the extension message is very important in raising awareness regarding new interventions and innovations. Fallow periods strategy was affected significantly by education level and *A. senegal* area at ($p > 0.05$). under the lack of fertilizers and pesticides applications, the fallow period remains the vital traditional practice to restore soil fertility. Farmers have to adopt this practice to guarantee satisfactory production of agricultural crops. Education level is very important to better understand the vulnerability and adaptation to climate change and variability. *A. senegal* are planted, in the past, according to the traditional gum bush cultivation cycle in which the fallow period is essential component. Fisheries was affected significantly by gender at ($p > 0.05$), the will be attributed to the fact that fisheries in the study area is practiced by women.

3.5.2 Factors determining adoption of enclosure, seed broad cast alternative source of energy and changing house pattern

At the study area, enclosures are affected significantly by education level at ($p > 0.05$). Moreover, grasses seed broadcast is affected significantly by areas of *A. senegal* at ($p > 0.05$). This finding is verified by the fact that farmers used to broad cast the seeds of grass at the same time of

broadcasting seeds of *A. senegal* before the preparation for the rainy season. Alternative energy sources are affected significantly by gender and number of livestock at ($p > 0.05$) in the study area. This finding could be verified by the fact that women usually use grasses for igniting fire and for other purposes. Changing house pattern is affected significantly by extension services and gender at ($p > 0.05$) due to the fact that houses construction in the study area is men responsibility. Table (7) shows the Factors determining adoption of enclosure, seed broad cast, alternative source of energy and changing house pattern.

Table 7: Factors determining adoption of enclosure, seed broad cast alternative source of energy and changing house pattern

Adaptation stratagy / Factors	enclosure		Grasses seed broadcast		Alternative energy		Changing house pattern	
	β	Sig	β	Sig	β	Sig	β	Sig
HH age (yrs)	0.051	0.301	0.017	0.707	0.083	0.082	0.005	0.929
Family size (no)	-0.361	0.069	-0.177	0.335	-0.212	0.277	-0.092	0.653
Extention service (dummy)	0.779	0.059	-0.205	0.589	0.499	0.226	0.946	0.029*
Education level (School yrs)	0.106	0.036*	0.065	0.170	-0.037	0.453	0.011	0.839
HH gender (dummy)	-0.386	0.439	-0.389	0.410	-1.277	0.010*	1.502	0.003*
Livestock (no)	0.002	0.886	0.006	0.678	-0.050	0.002*	0.008	0.612
A.senegal area (dummy)	-0.235	0.571	-0.808	0.046*	0.616	0.136	0.010	0.982
Constant	-0.596	0.704	1.354	0.359	-1.753	0.243	-2.589	0.118

*significant at $\alpha=0.05$; n=140 in all cases

3.5.3 Factors determining adoption of Plantation of *A. senegal*, Plantation of *hyphene theibica*, Sand dune stabilization and Shelter belt

In the study are, plantation of *A. senegal* is affected significantly by extension services, gender, and areas of *A. senegal* at ($p > 0.05$). This finding is attributed to the fact that men usually are responsible for sowing of *A. senegal* in gum gardens. It is logic; to sow *A. senegal* necessitates existence and ownership of gum garden.

Plantation of *hyphene theibica* is also affected significantly by extension services at ($p > 0.05$). While sand dune stabilization and Shelterbelt establishment are affected significantly by extension services and gender at ($p > 0.05$). This is attributed mainly to the fact that men are responsible for activities related to sand dune stabilization and construction of shelterbelts. Table (8) shows the factors determining adoption of Plantation of *A. senegal*, Plantation of *hyphene theibica*, Sand dune stabilization and Shelter belt.

Table 8: Factors determining adoption of Plantation of *A. senegal*, Plantation of *hyphene theibica*, Sand dune stabilization and Shelter belt

Adaptation strategy / Factors	Plantation of *A. senegal*		Plantation of *hyphene theibica*		Sand dune stabilization		Shelter belt	
	β	Sig	β	Sig	β	Sig	β	Sig
HH age (yrs)	-0.008	0.867	0.035	0.663	0.085	0.073	0.085	0.073
Family size (no)	0.056	0.774	-.235	0.435	-.151	0.433	-0.151	0.433
Extension service	-1.071	0.007*	2.487	0.021*	-1.164	0.005*	-1.164	0.005*
Education level (yrs)	-0.082	0.093	0.141	0.089	-0.015	0.756	-0.015	0.756
HH gender	-1.423	0.005*	-0.741	0.302	-1.516	.003*	-1.516	0.003*
Livestock (no)	-0.016	0.283	-0.017	0.406	-0.012	0.441	-0.012	0.441
A. senegal area	0.977	0.014*	0.847	0.161	-0.207	0.623	-0.207	0.623
Constant	2.100	0.170	-1.577	0.569	0.006	0.997	0.006	0.997

*significant at $\alpha = 0.05$; n =140 in all cases

These findings agree with (Diggs, 1991; Maddison, 2006; Semenza *et. al.*, 2008; Ishaya and Abaje, 2008; Akter and Bennett, 2009; Sampei and Aoyagi-Usui, 2009, who reported that different socio-demographic factors, age, exposure to mass-media, sex, and ethnic background, membership in environmental groups, education, and access to extension affect the perception of climate change.

4. Conclusion and Recommendations

The study concluded that Climate change and variability also resulted in negative impacts on the production of main food crops as well as increasing the prices of main food and cash crop which effecting food availability and food access for the household in the study area. Different initiatives were undertaken to support local communities to enhance their resilience by governmental institutions (Ministry of Agriculture and FNC), local NGOs (SECS), international NGOs, and

public efforts. The logistic regression model revealed the household socio-economic factors determining farmers' choice and adoption of adaptation strategies.

The study recommended that the adaptation strategies should be based on the indigenous knowledge and scientific findings in the field of environmental conservation. To enable workable and effective adaptation measures, ministries and governments, as well as institutions and non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making.

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