RESEARCH ARTICLE

ENVIRONMENTAL DEGRADATION IN THE SAHEL: A STUDY FROM WESTERN SUDAN-GHUBAYSH AREA

[1,] *Ahmed H. I. Elfaig, [2]Hamid Hamed Ibrahim, [1]Omer Egemi and [2]Mokhtar, J.

[1]Faculty of Geographical and Environmental Sciences, University of Khartoum
[2]School of Social, Development and Environmental Studies, Faculty of Social Sciences and Humanities, UKM

ARTICLE INFO	ABSTRACT
	This article focuses on environmental degradation in the African Sahel with a case study from western Sudan. The article aims at analyzing environmental degradation using environmental indicators, traditional ground based methods and secondary sources. Four hundred and twenty (420) headed households were randomly selected from twelve sample sites and questionnaire interviews were conducted to collect data on the environmental change indicators and causes. The descriptive statistical methods and Chi-square test were used in the data analysis. The results showed significant change in vegetation cover including disappearance of some vegetation species, wide spread of shrubs as well as dominance of Prosopis glandulosa around settlements' centers which explained 48.3% of the variation in the data set. A considerable segment of the respondents (17.4%) showed that Giraffa camelopard dlis, Asimus africanus and Struthio camel us disappeared from the area. The study pointed out that repetitive droughts, expansion of agricultural area from 9.8% to 41.4% of the land, charcoal making and increase in animals and human population have been the main causes of environmental change ($\rho = 0.01$).

INTRODUCTION

Environmental degradation is one of the major environmental problems that affect the African Sahel Area. Degradation means changes in both quantity and quality of the environment which include the decrease in vegetation cover and losses of biodiversity (**Abusin, 1991**). Degradation has also been defined by **Elfaig (1996)** as "depletion of natural resources, overexploitation of renewable resources, destruction of forests, spread of shrubs at the expense of dense vegetative areas and forests, extinction of wildlife, disappearance of many species and appearance of new ones". In the year 1992 the United Nations Environmental program (UNEP) defined the term as "the decline in the productive capacity of an ecosystem due to processes induced mainly by human activities" (**UNEP, 1992**). Environmental degradation and change are widely spread phenomenon in the Sahel. Study on the evaluation of environmental degradation in northern Ethiopia revealed that evergreen scrub vegetation type appear to be expanding with a general decrease in biomass of vegetation as a result of wood collection for fuel and other domestic uses (**Enrico *et al.*, 2003**). Bush land appears to be expanding with the same trend (**Enrico *et al.*, 2003**). The environmental degradation in the study area was vaguely mentioned by the (UNEP) report of 1997.

*****Corresponding author: Ahmed H. I. Elfaig,*
Faculty of Geographical and Environmental Sciences, University of Khartoum.

The report stipulated that in the last 25 years about 61 million hectares in northern Sudan including the study area were degraded. This report is supported by UNEP's 2007 report which estimated that the northern desert boundary in Sudan has shifted southward 50 km, since the 1930s, which indicated a considerable risk of degradation in the study area (**UNEP, 2007**). The ecosystem in this area is characterizes by high rainfall variability and high water deficiency (**Elfaig *et al.*, 2013**), low sustainability, low resilience, low carrying capacity and restoration as it resembles the general features of the Sahelian ecosystems. This article aims at analyzing environmental degradation in western Sudan (Ghubaysh area) which is part of the Sahelian zone using environmental indicators, traditional ground based analysis along with quantitative and qualitative methods techniques.

MATERIALS AND METHODS

This part focuses on the consciously applied methods that provide some geographical description of the study area, sample sites sampling, data collection and analysis to come out with comprehensive results on environmental indicators and causes.

The Study Area: Geographical Description

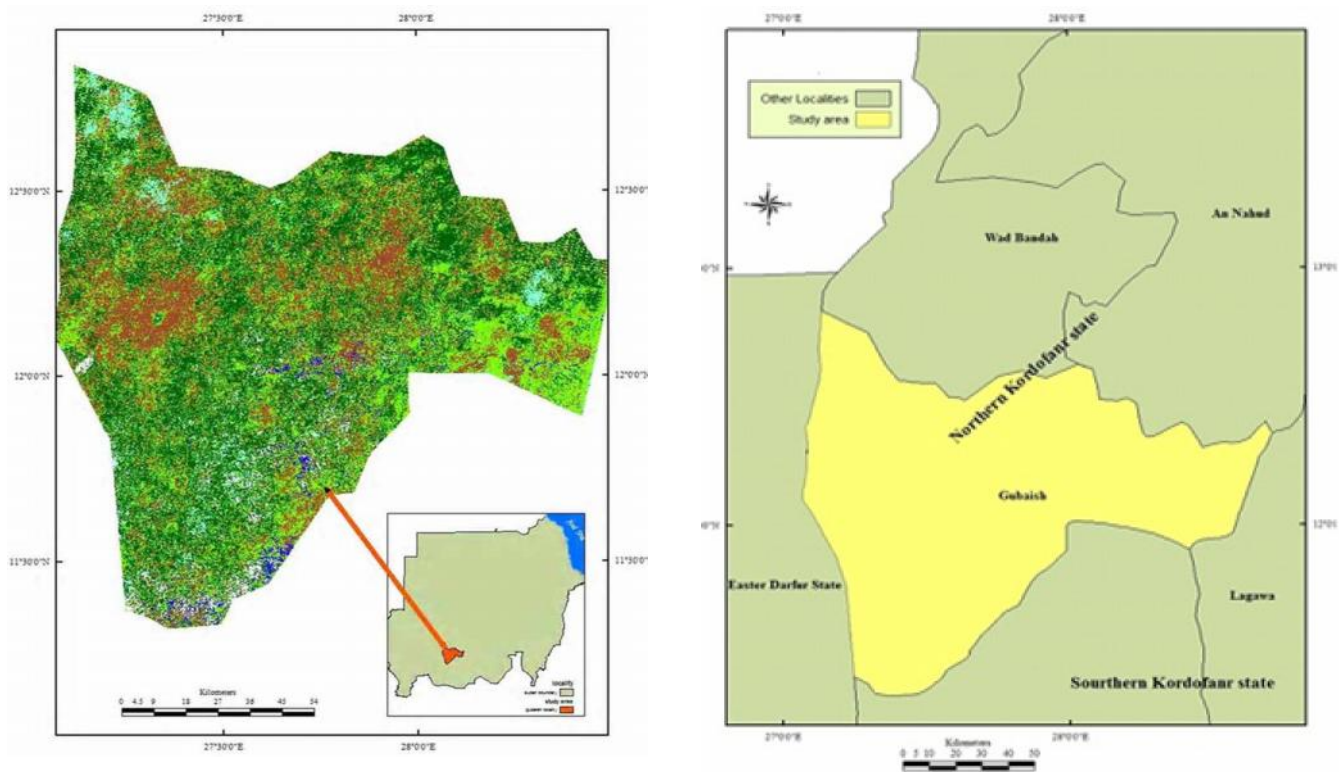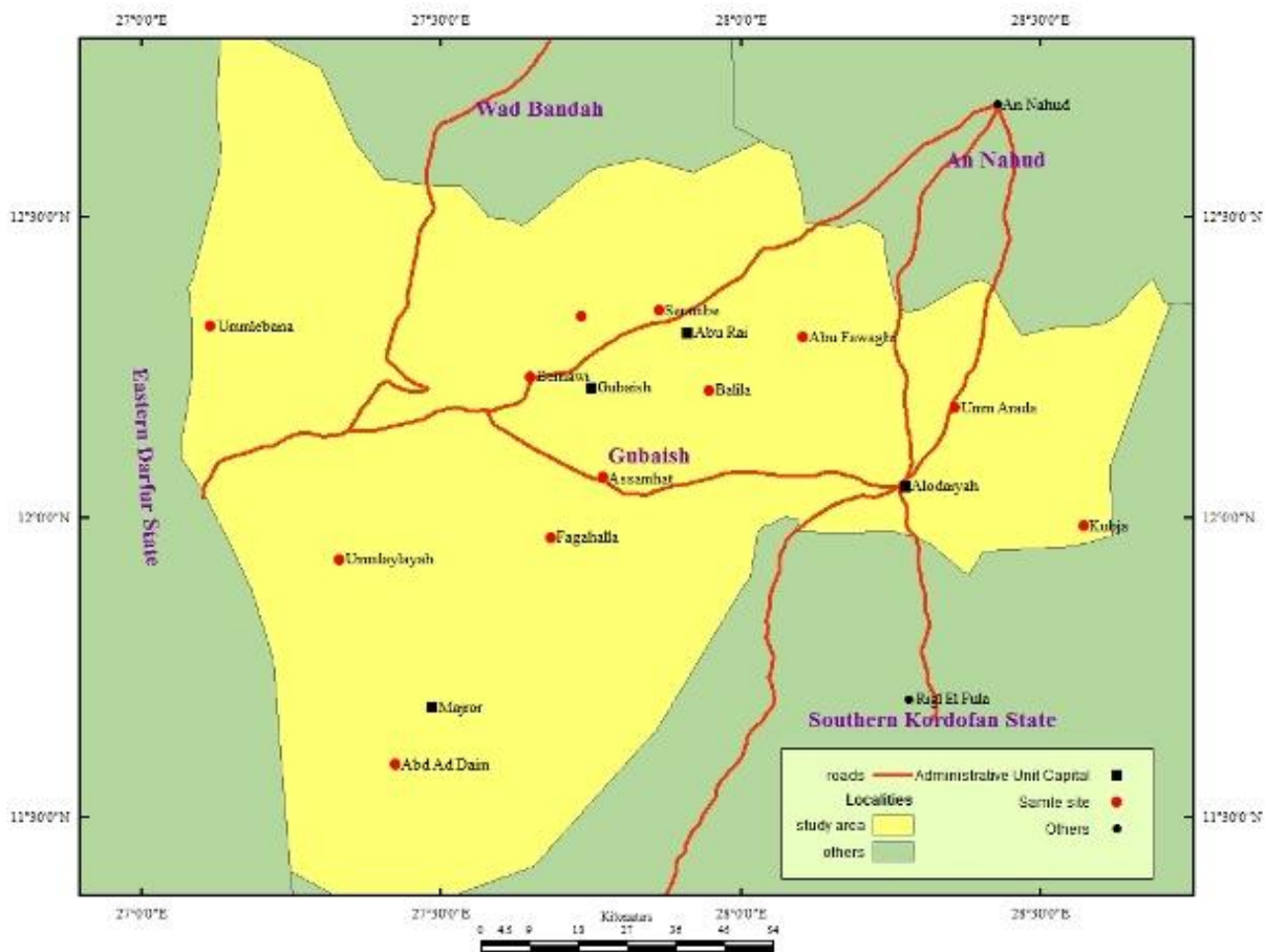This study was conducted in Ghubaysh area in West Kordfan State.

Fig. 1. Location of the Study Area

Fig. 2. Sample Sites

The study area lies between latitude 11^0 18' 56" to 12^0 49' 39" N and longitude 27^0 3' 29" to 28^0 30' 44" E covering about 14000 km² as shown in Fig.1. This area exhibits a typical Sudano-Sahelian zone which is characterized by vulnerable environment, high rainfall variability and low relative humidity (**Elfaig *et al*., 2013**) as well as relatively high temperature throughout the year. The maximum temperature mean was $(30C^0)$ and the minimum temperature mean was $(14C^0)$ for the period 1970-2010 (Metrological Authority, Khartoum, 2012). This area is made up of four administrative units (localities), namely Ghubaysh, Aburaiy, Almajroor and Alodaiyah. The total population of the area, based on Sudan's Fifth Population and Housing Census 2008 is 290619 persons (**Central Bureau of Statistic 2009**). The gender ratio for the total population is 48.3% male and 51.7% female. Based on the population's mode of living, 88.2% were rural, 7.8% urban and 4% nomads (**Central Bureau of Statistic 2009**). Livelihoods are fundamentally based on traditional agriculture and nomadism supported by petty trade in environmental products such as charcoal making, building materials; and Gum Arabic collection.

Sampling, Data Collection and Analysis

The sample sites and the target population were approached within a broader framework coupled with the centrality of the household as a unit of investigation and analysis. Realizing the objectives of the study, it necessitates rendering the household a central position that will more likely make it possible to understand the causes of environmental degradation since the households are responsible for most of the decisions related to the rural community practices.

Sample Sites and Size

Twelve (12) sites were intentionally selected from the four administrative units as shown in Fig. 2. Most of the public amenities and services such as schools, hospitals, permanent water sources and markets are found in these selected sites. The sample size was determined based on the total number of households in the selected sites (4660 households). Considering the confidence level of 95% and confidence interval of 4.5 coupled with the equations 3.1 and 3.2. A total of 420 households were randomly selected.

$$n = \left(\frac{\sigma \times 1.96}{SE} \right)^2 \qquad \text{Equation (3.1)}$$

n: is sample size
SE: is standard error
1.96: is the confidence level at 0.95

$$(\sigma) = \sqrt{\frac{\sum (X - \bar{X})^2}{N}} \qquad \text{Equation (3.2)}$$

The sample size was divided among the administrative units based on the proportion of households and presented in Table 1. Data on the samples showed that 92.1 were male while the rest (7.9%) were female. No biases towards the male because the women headed households are few. They are widows, divorced or their husbands were absent (migration) which reflects gender discrimination in such rural communities of western Sudan.

Table 1. Sample Size

Administrative unit	Number of households in selected sites	Number of selected households	Percent of selected households
Gubaish	1682	152	36.1
Abu Rai	573	52	12.3
Alodaiyah	1594	143	34.2
Almajror	811	73	17.4
Total	4660	420	100

Questionnaire sheets were distributed among the respondents combined with the ground truth observations were carried out together with the climatic elements records and consultation of the available previous studies and records; to collect data related to indicators and causes of environmental degradation specially data on vegetation cover and wildlife. The descriptive analytical methods in terms of frequency distribution and percentages, simultaneously, with Chi-square test have been used in the data analysis.

RESULTS AND DISCUSSION

The secondary sources, ground truth observation and questionnaire sheets provided several evidences for the processes and signs of environmental degradation. The evidences from the literature can be summarized as follows:

1. The United Nations Environmental Program (UNEP) report of 1996, mentioned that in the last 25 years, about 61 million hectares in northern Sudan including the study area have experienced degradation (**UNEP, 1996**).
2. The UNEP report of 2007 estimated that the northern desert boundary in Sudan has shifted 50 km southward, since the 1930s. This means that the study area is at a considerable risk of degradation.
3. Harrison and Jackson study 1958 stated that the study area was once densely vegetated area. According to Smith (**Smith 1949**) very nutritious grasses such as *Schoenefeldia gracitis* and *Cympopogan nervatus* were widespread; currently this is not the case.
4. There were many wildlife species used to be in the area such as *Giraffa camelopard dlis, Gazelle dorcas, Asimus africanus, Hyanena hyaena, Eryhrocebus patas* and *Phacochoerus pardus*. These wildlife are no longer exists.
5. In their studies of trees and grass in Western Sudan **Elsamani (1984) and Elmahi (1986)** concluded that the area used to have a good in vegetation cover including both annual and perennial grass. At present, natural resources in the study shows symptoms of environmental degradation and face severe and alarming degradation compared to what it used to be decades ago.

Ground Truth and Observation of Degradation

The ground truth observation revealed many signs of environmental degradation. These include:

A. disappearance of some trees, some tress become very few, wide spread of shrubs, reduction in *Accacia Sengal* and decrease in diversity of tree species as shown in Table 2.

Table 2. Vegetation Cover Change as Degradation Indicators in Gubaish Area

Vegetation Name	Exist abundantly	Few	Very Few	Disappeared
Maerua crassifolia				√
Combretum glutinosum			√	
Combretum hartmannianum			√	
Advansonia digitata	√			
Bauhinia rufescens		√		
Accacia albida		√		
A. Mellifera				√
A ccacia nilotica	√			
Accacia nubica	√			
Accacia Sengal		√		
Accacia seyal				√
Accacia tortilis raddiana				√
Albizia amara	√			
Ziziphus spinachristi	√			
Balanites aegyptiaca	√			
Commiphora Africana			√	
Lannea fruticosa				√
Scierocary a birrea	√			
Boscia senegalensis	√			
Guieva senegalensis			√	
Detarimmicrocapum				√
Prosopis glandulosa	√			
Leptadenia pyrotechinca	√			
D. aegyptium		√		
Eragrostis.sp		√		
Brachiaria.sp			√	
Z. diphylla				√
Blepharis. Sp				√
Ipoeamea sp		√		
Zorina diphylla	√			

Source: Field Work 2012

The table shows that many trees, at least eight (8 types), have disappeared from the area. The disappearing trees include: *Maerua crassifolia*, *Detarimmicrocapum*, *Accacia albida*, *Balanites aegyptiaca* and *Lannea fruticosa*. Other tree species such as *Combretum glutinosum*, *Combretum hartmannianum*, *Commiphora Africana* and *Guieva senegalensis* have become very rare in existence.

B. Wide Spread of Shrub and Reduction in *Accacia Sengal*

The field survey showed that shrubs dominated and widely spread in the study area. This area used to be densely vegetated area with long trees rich in both composition and structure as mentioned by many scholars such as **Harison and Jackson (1958) and Booth (1965)**. The *Accacia Sengal* which was abundantly existed and widely spread in the study area (Elmahi 1987) becomes very few in existence and spread in clay soils and low land area. The fieldwork showed that most of the area used to be covered by *Accacia Sengal* is replaced and dominated by grass species such as *Zorina diphylla*, *Ipoeamea sp* and *Eragrostis. sp*. This result has been supported by 73.3% of the respondents. The issue of *Accacia Senegal* is a very important issue in international literature. It deserves more space and analysis, even its importance in Kordofan rural and

urban economies as well as Sudan national economy. When USA operationalized its economic sanctions on Sudan, Gum Arabic was the only commodity exempted.

C. Spread of Termites Mound and Reduction in Biodiversity

Widespread presence of termites mound around trees stems has been observed throughout the area indicating strong evidences of environmental degradation in the area. The ground observation has also revealed the dominance of mono-species in a single community such as *Colotropis procera, Zorina diphylla*, *Ziziphus spinachristi*, *Prosopis glandulosa* and *Boscia senegalensis* as shown in Fig. 3A and 3B which was not the case in the 1960s. These trees are unpalatable trees and have low nutritional values as confirmed by 62% of the respondents.

Fig. 3A. Dominance of *Colotropis procera* in Ghubaysh Area

Fig. 3B. Dominance of *Colotropis procera* and bare land Ghubaysh Area

D. Decrease germination in new tree species and appearance of inferior ones

The results showed that the existence of some valuable trees such as *Adasonia digitata*. However, it is very rare to find

germination of new generations of the *Adasonia digitata*. Even the old ones are falling down (Fig. 4.) This type of trees most probably germinates and grows up under more humid conditions. Results also showed that new trees species germinated, such as *Zorina diphylla* and *Prosopis glandulosa*. These trees tolerant to water deficiency and characterizes by having deep roots and high competition to plants species. The respondents (48.3%) argued that *Prosopis glandulosa* are the dominant species around some villages in the area. Yet, some grass species disappeared from the study area and some of them are few in existence as presented in Table 2. These grasses are *poeamea sp*, *Blepharis. Sp* and *Brachiaria. sp*. These species are palatable and have high nutritional values. The disappeared of these species would no doubt affect the grazing system in the area as well as livestock raising in general. The results of existing trees clearly indicated that the most widely spread trees type either xerophytes like *Ziziphus spinachristi* and *Prosopis glandulosa* or tropophytes which practices the function of hygrophytes during the rainy season and xerophytes during the dry season.

Fig.4. Falling of *Adasonia digitata* in Gubaish Area: Indicator of Degradation and Change in Vegetation Cover 2012

The deterioration in vegetation cover has been associated with enormous decline in wildlife and biodiversity. The field survey showed that most of the wildlife prevailed in the study area during the 1960s and 1970s such *Giraffa camelopard dli*, *Asimus africanus*, *Panthera leo*, *Eryhrocebus patas* and *Struthio camelus* have disappeared from the area. Existing wildlife species are either very few or few in existence such as *Hyanena hyaen*, *Gazelle dorcas*, *Panther pardu*, *Numida meleagris* and *Lamprotornis chalybaeus* (Table 3). This result has been supported by the opinion of 77.6% of the respondents. These different types of wildlife depend on grass species and trees for their shelter and nutrition as well as on each other interns of food web and food chain. The deterioration and decreased in both quantity and quality in vegetation cover had a major role in disappeared of some wildlife species. The results also show that 78.1% of the respondents agreed that new big rats appear in the area as well as desert rats.

Table 3. Wildlife Change as an Indicator of Environmental Degradation in Gubaish Area

| Wilde Animal Name	Existence		
	Few	Very Few	Disappeared
Giraffa camelopard dlis			√
Gazelle dorcas		√	
Asimus africanus			√
Panthera leo			√
Hyanena hyaena		√	
Eryhrocebus patas			√
Phacochoerus pardus			√
Panther pardus		√	
Madogua satiana		√	
Sagittarius serpentarius			√
Struthio camelus			√
Upupo epops		√	
Numida meleagris	√		
Chlanydotis undutata		√	
Pelecanus onocrotalus		√	
Lamprotornis chalybaeus	√		
Ardea cinerea		√	
Ciconia abdimii		√	

Source: Field work 2012

The results also showed that the majority of the respondents (65.7%) confirmed the changes in some vegetation species and wildlife type as shown in Table 4. Simultaneously, a considerable segment of the respondents (31.7%) confirmed the change in the general appearance of biodiversity as an indicator of environmental degradation

Table 4. Respondents' Characterization of Environmental Change in Ghubaysh Area n =420

Identified term	Frequency	%	Cumulative %
Disappeared of some vegetation species	203	48.3	48.3
Disappeared of some wildlife type	73	17.4	65.7
General change in the appearance of biodiversity	133	31.7	97.4
Others	11	2.6	100

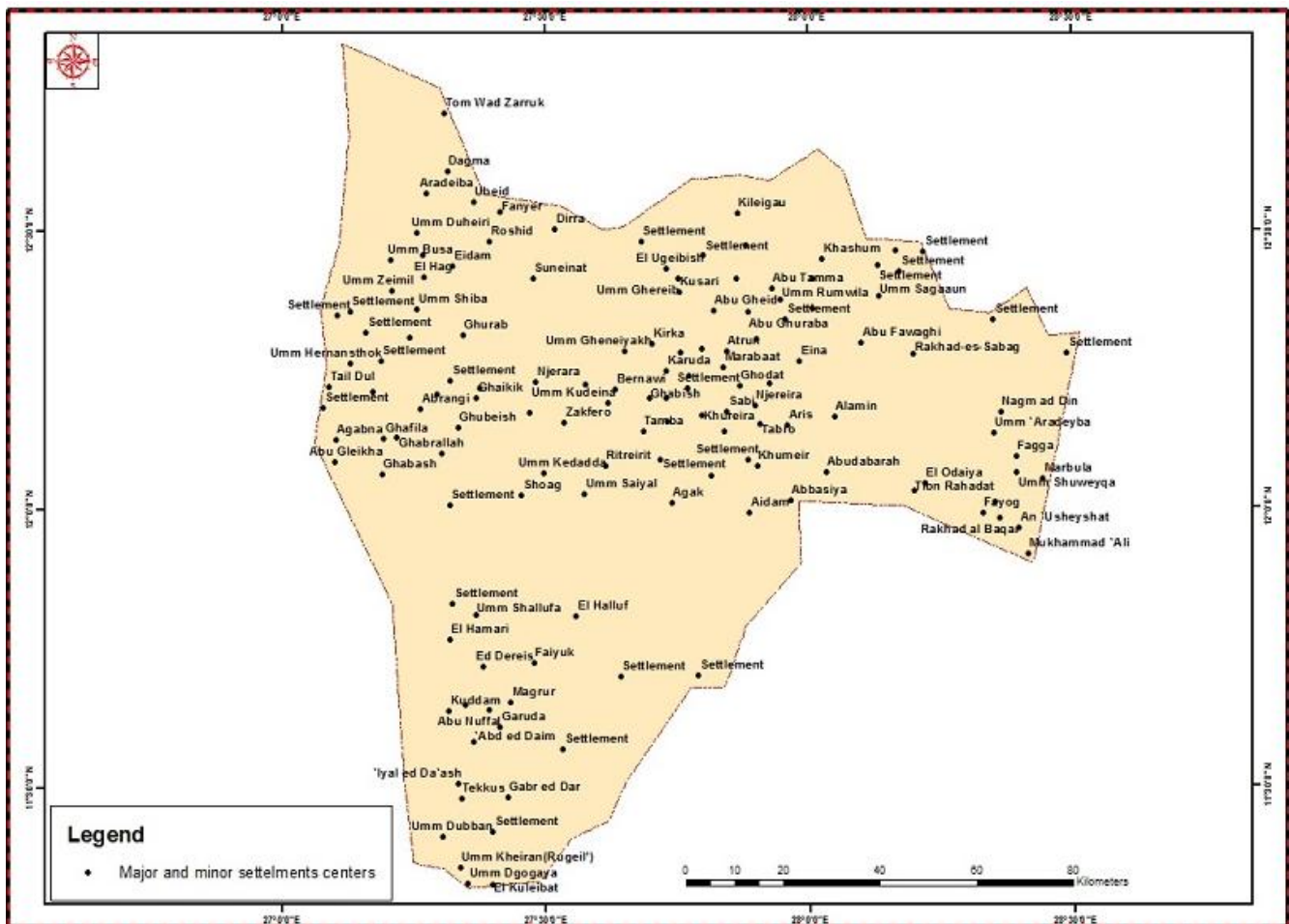### Causes of Environmental Degradation in Ghybaish Area

The natural and dynamic human factors are the causes of environmental degradation in the study area. These include drought, population pressure, agricultural expansion and practices, traditional building materials, charcoal making and animals raising. The most natural destructive features which are now leading to degradation of natural resources in Ghubaysh area are drought associated with rainfall variability and fluctuation. The rain usually falls during autumn (July to mid October). The rain occurs as a result of the movement of the (ITCZ) Intertropical Convergence Zone (**Eltom 1975; Abdall 1992**). Realizing the very high natural variability of climate, the data available indicates that from 1971-2010, the region was struck by three major drought, during 1971-1973, 1983-1985 and 1991-1993. The meteorological records proved high rainfall variability and provided real indication of drought years during the period of 1970-2010 as shown in Fig. 5. The relative humidity in the study area has been low during the last twenty years (32-45%). This low relative humidity may increase the processes of evaporation and lead to early drying of crops and grass.
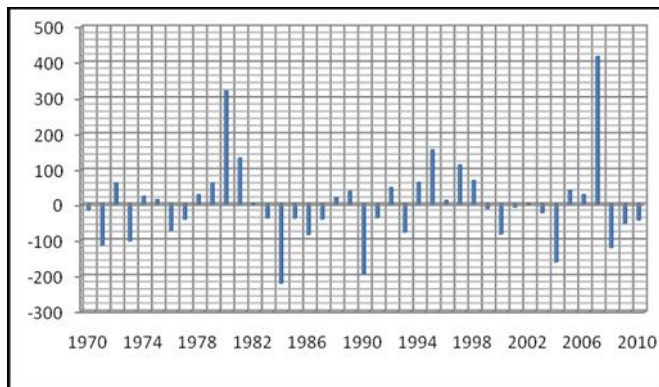
Source: Meteorological authority, Khartoum 2012

Fig. 5. Rainfall fluctuations in Ennuhud station (nearest meteorological station

fuel wood around the major settlements centers, shortening the fallow cycle and demand for more land to feed more people. The study area has a total population of 290619 which reveling density of 20 persons per km^2 (**Central Bureau of Statistics 2008**). The continuous increases in population numbers have led to drastic increase in the numbers of settlements centers. The statistical records showed that the total settlements centers in the study area are one hundred and forty villages (including small villages) as shown in Fig. 6. These villages are not systematically distributed; they are unplanned village and their establishments are bounded by the existence of permanent water sources. Most of these villages are built from traditional building materials and the inhabitants use the traditional charcoal and fuel wood for their daily consumption which excrete more pressure on the natural environment and cause more degradation.

Source: Central Bureau of Statistics 2012

Fig.6. Settlements Centers in Ghubaysh area

Population Pressure

Many arguments about the causes of environmental degradation focus on the growth of population. Now population growth is fast in most of the regions; the study area is not an exception. The population growth rate in the rural areas of Sudan including the study area is 2.8% per annum (**Central Bureau of Statistics 2008**). This has direct consequences on the environment, due to growing demands for

Expansion of Agriculture

The traditional farming sector is based on family labor, small scale production and limited capital input (**Salih 1987**). The traditional agriculture has remained the main economic activity and is practiced by the majority of the population (69.3%). The environmental degradation can be explained by the rapid horizontal expansion of traditional agriculture in the last four decades (Table 5). This includes shifting cultivation through

effects on vegetation and forest clearing. Expansion of agriculture creates competition over natural resources especially in the area vulnerable to drought like the study area. This expansion emphasizes on the production to enable people to attain self sufficiency. The expansion of cultivated areas coupled with irrational farming practices such as early land clearing and use of fire in the clearing process together with continuous cultivation which carried out by (88%) of the respondents lead to the degradation of the environment in the study area.

Table 5. Expansion of Cultivated Areas in Ghubaysh (1973-2010)

Year	Cultivated area (km^2)	% of agricultural area
1973	1419	9.8
1987	2121	14.7
1999	2553	17.7
2006	3807	26.4
2010	5965	41.4

Source: Extrapolated and manipulated from the satellite images of indicated years

Traditional Building Materials

The cutting and using of green trees as building materials play a major role in environmental degradation and indicated by 9% of the respondents. These green trees and forest have great effects on human behavior because it provides some work opportunities; provides human and animals with food; as well as it has a genuine role in traditional medicine. The green trees in the Ghubaysh area are used as traditional building materials. The destruction of the trees in Ghubaysh area is mainly for wining timber and fuel. The inhabitants used trees to build enclosures, fences, huts and houses. They are also use large a mounts of wood in their local industry such as local beds, and tool handles. These materials are either brought directly from the forest or bought from the markets as shown in Fig.7. Almost all households in the area use wood for building and construction in one form or another. It is worth mentioning that every single hut needs four hundred and fifty units of selected wood to complete its construction as presented in Table 6.

Source: Field work (2012)

Fig. 7. Use of green trees as traditional building materials in the Ghubaysh Area

Table 6. Types and Number of Wood Needed to Build a Single Hut in the Ghubaysh area

Number of wood (unit)	Scientific name	Used for
Fasting different parts	*Lannea fruticosa*	200
Carry the roof	*Dichostchys glomerata*	17
Supporting fences	*Dichostchys glomerata*	23
Straw materials	*Grewia spp.*	200

Animal rising as a Cause of Environmental Degradation

The environmental degradation in the area includes rangeland degradation through the system of animal rising such as animal migration, settling of animals around major water centers and raising of animals on crop stalks and private fallow areas. This is accentuated by overstocking and overgrazing. Open grazing system of pasture means the communal use of pasture by any numbers of tribes and animals. This has a direct effect on pasture land. Large numbers of animals concentrated on a limited resource that is beyond a pasture's capacity, hence, elimination and degradation of grass species.

Fig.8. Herd diversification and adaptation to harsh environmental conditions

The field survey shows that most of the respondents (71.7%) owned a considerable number of animals; furthermore, the

balance of 28.3% of the respondents also owned animals even though in smaller numbers as it can be understood within the context that they have less than ten heads of animals which indicated herds diversifications that give a sense of reduction of losses during the drought and dry years i.e. sheep and cattle are less tolerant to drought and most probably will die. Goats and camels can adapt to harsh environmental conditions and can depend on trembling of tress as shown in Fig. 8. The overstocking of animals can be explained by high animals' population density which is 74 head per one km^2 (**Livestock Resources Unit, Ghubaysh Locality 2012**). This official statistics showed only the animals owned by the tribes of the area itself, but had failed to include the large numbers belonging to those who visit the region from the north area especially during the dry season. The results also show that (44.3%) of the respondents argued that the concentration of animals around permanent water centers during the dry season leads to environmental degradation.

The environmental degradation is accentuated by the processes of charcoal making and fuel wood which are the major sources of energy supply in the study area. Two technical processes in charcoal making are the main contributors to environmental degradation. These are burning wood in open space and using of green trees in charcoal making which are identified by the 8% of the respondents. The field survey revealed that charcoal has become a commodity and charcoal trading has become very active because charcoal is an important product that brings in money or cash for the traders and families. Simultaneously, the failure of agricultural seasons has pushed many families to practice charcoal making and to adopt it as a job. The prefer wood for charcoal making is a green wood. The most preferred trees types are *Dichostchys glomerata* and *Dichostchys glomerata* which become very few in the study area due to excessive cutting and use. These dynamics contributing factors to environmental degradation were tested using Chi-square and the five percent (0.05) significance level was used in making decision about the results as shown in Table 7.

Table 7. Causes of environmental degradation in the Ghubaysh area

n =420

Causes of environmental degradation	Observed	Expected	Residual	Percent
Agricultural expansion and operations	269	105	164	64
Charcoal making and traditional building materials	72	105	-33	17
Increase in animal population and human settlements	62	105	-43	15
Others	17	105	-88	4

df= 3, Chi-square value = 357, (ρ = 0.01)

The results showed that the traditional agricultural expansions and operations is a major contributor to environmental degradation as identified by 64% of the respondents. The results also showed big differences between expected and observed value in each factor and its significance at the 0.01 level (ρ = 0.01).

Conclusions

Environmental degradation and changes are wide spread and progressively expanding phenomena in Ghubaysh area. The changes in vegetation cover are prominent features of environmental degradation. The change in vegetation has been associated with enormous depletion of wildlife and biodiversity. Nearly all wild animals and mammals have disappeared from the area and replaced by wide presence of desert rats indicating prevalence of desert environment in the Ghubaysh area. The repeated droughts and global climate change, expansion of traditional agriculture , dramatic increase in human and animal populations under conditions of poverty and traditional house building technology based on biomass materials are the main causes of environmental degradation. The high density of livestock population (74 head per km^2) (**Livestock Resources Unit, Ghubaysh Locality 2012**) and the accelerated tendency of capital investment in livestock resources at the level of both the household and the private sector reflect a bleak environmental trajectory in Ghubaysh area of Western Sudan.

REFERENCES

Abdalla, M. K. 1992. The climate of the Red sea Area, Sudan. Un published M.A thesis. University of Khartoum.

Abusin, M. E. 1991. Disaster Prevention and Management in Sudan. Khartoum: Khartoum University Press.

Booth, G.A. 1965. Study of the Gum-Arabic and the supply of other forest produce in relation to land use planning. Athens: Doxiaches Associates

Central Bureau of Statistic. 2009. 5Th Sudan Population and Housing Census. Khartoum, Sudan.

Central Bureau of Statistics, 2009. 5Th Sudan Population and Housing Census, priority result. Khartoum, Sudan. Khartoum, University of Khartoum press

El Sammani, M. O. 1984.The impact of water supply generated on ecosystem with suggested strategy for action. A paper presented to the national seminar on the indicators of environmental changes and desertification. Khartoum friendship hall, 4 March 1984

El Tom, M.A. 1975. The Rains of the Sudan. Mechanisms and Distribution, Khartoum, University of Khartoum press

Elfaig, A. 1996. Agro-pastoralists Adaptation to Environmental Change in Khuwie Area. Unpublished M.Sc. Thesis, University of Khartoum. Khartoum

Elfaig, A. H. Ahmed, Ibrahim M. Eltom and Abdelrahim Salih. 2013. Rainfall Variability in the Sahel: A study from Sudan (1970-2010). *International Journal of Scientific and Research Publications*, 3(11).

Elmahi, Y. A. 1986. A Geographical Survey and Analysis of some short and long term changes in the Tree cover of the centeral part of Kordofan region. Unpublished M.A. Thesis. Department of Geography, University of Khartoum.

Enrico F, Paola G, Irene O, Daniel S, Woldu Z. 2003. Measuring the effects of human impact on vegetation by integrating phytosociology and remote sensing in a fuzzy set approach. *J. Veg. Sci.,* 14(5): 751-760.

Harison, M. and Iackson, J. K. 1958. Ecological Classification of the Vegetation of Sudan. Forest Bulletin No. 2. Forest Department Khartoum.

Livestock Resources Unit. 2012. Ghubaysh Locality 2012-Sudan.

Salih, M. A. 1987. Agrarian Change in the Central Rain lands: Sudan a socio-economic Analysis. Scandinavian Institute of African Studies, Uppsala, Uppsala University

Smith, J. 1949. Distribution of Trees Species in the Sudan in Relation to Rainfall and Soils Texture. Ministry of Agriculture, Sudan government, Bulletin no.4, Khartoum.

Sudan- Metrological Authority. 2012, Gubaish Metrological Station, 2012-Sudan.

UNEP. 1992. *World Atlas of Desertification*. Nairobi, Kenya: UNEP.

UNEP. 1996. *World Atlas of desertification*. 2nd edition. Arnold. London.

UNEP. 2007. Sudan Post-Conflict Environmental Assessment. Nairobi, Kenya.

****