

Original Research Article

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Assessments of the Effect of Land use/ Land Cover Changes on Soil Properties in the North Eastern Nuba Mountains Region, Sudan

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ABSTRACT

The study was carried in Abu Jubeiha area in Northeast Nuba Mountain, South Kordofan region, Sudan. In the last decade an excessive changes have been realized in Abu Jubeiha area due to two reasons; civil war and its impact that causes internal migration and the drought which hits the whole Sudan region. Together, the civil war and the drought have caused excessive environmental changes. Consequently, cultivated lands were abandoned; crop production decreased and the forests were exposed to excessive wood cutting for daily needs especially close to the new settlement areas for displaced people. As the civil war restricted the regional movements of pastoralists and the nomadic tribes with their herds this has exerted tremendous pressure on safe non war zone transitional areas like Abu Jubeiha area. The study was intended to investigate the vegetation cover changes over time 1986-2005(civil war and peace span in the Nuba Mountains areas)as well as to detect its effect on soils characteristics at Abu Jubeiha area. The use of Remote Sensing and GIS techniques enabled classification of the area into dense forest, moderate forest, light forest and bare soil with an accuracy of about 64%.It study realized that 38% of the forested area were lost in between1986-2005 with an annually rate of about 1.8%. The forest clearance was increased two folds in the period between 1999 and 2005 (Peace span) compared to the period between 1986 and 1999 (War span).Routine soil analyses have been carried in relevant to vegetation cover. As well, soils dynamics were affected by land use activities and with the prevailing climatic conditions. The study concluded that civil war and the prevailing severe climatic conditions at North Eastern Nuba Mountains have resulted in more pressure on land resources at this area. The consequent soil and land degradation at the area manifested in the verified land cover/ land use changes have as well adverse effects on dynamic soil properties.

Keywords

Nuba Mountains,
Land Cover/
Land use
Changes, Land
degradation,
Remote sensing,
Geographic
Information
System (GIS).

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Introduction

The first serious sign of soil degradation in the Sudan was reported by Kennedy-Cooke (1944). The flat clay plains and sandy areas of the Sudan are continuing exposed to heavily overgrazing, over-cultivation, and cutting of trees for domestic purposes. Mechanized rain-fed agriculture and shifting cultivation have increased from about 2.0 million ha in 1954 to about 14 million ha in 1994, a rate of 300,000 ha per year (Tohill, 1954; Ministry of Environment and Tourism, 1996). Atta El Mouta, (1985) reported that wild fires are consuming about 35% of the natural range productivity annually. While Salih (1996) revealed that the effect of opening five thousands and five hundreds (5500) boreholes wells in anti-thirst campaigns during the period 1960–1990, led to vegetation denudation and soil pulverization. In this regard, Ayoub (1997) reported that about 400 million *Acacia* trees being uprooted annually for rain-fed cropping,

Land degradation and desertification in Sudan have been assessed for several times within global and regional attempts. Although it was agreed that severe degrees of land degradation are caused by human factors but different estimate levels have been noticed. The highest estimations were stated by Dregne (1991) in comparison to UNEP (1977) and FAO/UNEP (1984). GLASOD soil degradation assessment shows that severe and very severe degradations make 58 million ha. Difference between assessments, according to Ayoub (1997) could be due to the different methods followed where some of which focused on vegetation degradation without significant soil degradation.

However, the Sudan experienced different types of soil degradation; the wind erosion

in the hyperarid and arid zones of Kordofan and Darfur where the vegetation is poor and soil particles are loose. Topsoil loss through sheet erosion is a common type of water erosion in the semi-arid and arid zones and formation of gullies is an extreme form. The rich soils of the Nuba Mountains, Southern Kordofan are experiencing high topsoil loss; mainly caused by clearance of sloping terrain, the use of heavy machinery and mono-cropping.

The major cause of soil degradation beside the known traditional ones is the imbalance population in the Sudan since the majority live in arid and semi-arid zones (UNESCO 1997). Within national interest for a sustainable use of the natural resources, many on-going pilot projects scattered in southern Kordofan region to promote rainfed farming management practices to sustain and ensure land productivity. This has resulted in deterioration of productivity suggesting that scientific and technical knowledge of the agricultural environment, interactions between land components (soil, LU and LC) and their change over time is essential to promote productivity. The objective of this study is to understand dynamics of soil as affected by land use and land cover with quantitative data to assess the magnitude of soil loss/condition under different land use and land cover types.

The study area is part of vast undulating forested region, underlain by Precambrian Basement Complex, located in the East North Nuba mountains, South Kordofan State between 11° 23 08.79 -10° 52 48.17 N and 30° 00 05.99 -31° 28 04.91' E, within the Universal Transverse Mercator projection (UTM) zone 36 N, in semi-arid zone (Figure 1). The climate is characterized by a rainy season (July-October) and dry season. The average annual rainfall is between 500 to 850 mm, with annual average temperature

between 30°C and 35°C. Maximum average monthly temperature of about 39° occur in the three months preceding the wet season, minimum average monthly temperature vary between 17°C and 20°C and occur at highest of the dry season. The relative humidity is low (20-30%) in the dry season and rises to about 80% in the wet season. Winds are generally moderate (5-6Km/hr.) and common throughout the year, (Van der Kevie, 1973). The vegetation composition changes with rainfall from North to South. The most characteristic species are *Acacias* sp.; *A. mellifera*, *A. seyal*, *A. senegal*, *A. compylacantha*, *A. fistula* and *A. drepanolobium*. *Ficus* spp. are dominant on hill sides such as *F. populifolia*, *F. glumosa* with some other species like; *Boswellia papyrifera*, *Combretum hartmannianum*, *Andropogon gayanus*, *Pennisetum pedicellatum* and *Hyphae nethebaica*. The grasses are *Aristida* species, *Elyonurus royleanus*, and *Sectaria pallide-fusca*.

Materials and Methods

Materials

Remote Sensing data comprise of multi sensor and multi temporal data. Satellite data include data from Landsat ETM and ASTER images. Multi temporal Landsat were acquired on 15th November 1986 and 27th November 1999 and ASTER image ACQUIRED on 15th Feb. 2005. Digital Elevation Model (DEM) from GLCF online data, topographic maps (Sudan topographic sheets of Rashad, Melut and Talodi at scale 1:250000) and geological map of scale 1:1,000,000 (GRAS, 1986).

Soil map of North and South Kordofan at scale 1:250,000 (Pacheco and Dawoud, 1976) and semi detailed soil map of Eissa (1980), soil survey tools, digital camera, Garmin 12 XL GPS and software such as

PCI geomatica. Matlab and Gamma Design were used. Three subsets of Aster image were prepared and then printed at 1:50,000 scale (False Color Composite) for navigation purposes. Four weeks of intensive field work carried to collect ground truth information and to characterize the soils and collect soil samples along the survey area.

Methods

Images Analysis and Maps Producing

Images (Aster) were Geo-rectified, converted to UTM and resized into 28.5 m resolution to match with the ETM image (1986, 1999). Atmospheric correction was applied to minimize the effect of atmospheric conditions difference between images.

Data Transformation

Bands selection and reduction techniques have been done according to developed (Bosch and Rand 2002). Correlated bands transformed into a number of uncorrelated components and then the Principal Component Analysis (PCA) was applied to produce more colorful color composite images to speed up visual analysis and classification of the multispectral image (Jensen, (1996) and RSI, (2004)).

Image Classification

Unsupervised classification was carried and training areas representative of each land cover type were collected during 2005. Groups of pixels were selected from the area of known cover types. Areas of mixed land cover were not considered in order to avoid overlaps in training samples. The Maximum likelihood algorithm was used using PCI geomatica 10. The algorithm considers the spectral variability within each category and

the overlap that may occur among different classes (Campbell, 2002).

Classification Accuracy Assessment

A set of random reference pixels were used. Overall accuracy and overall Kappa statistics were measured (Congalton, 1991, Kerle et al. 2004). The overall accuracy is weighted by the number of samples/pixels in each class. The relation of the test sample data was summarized in an error/ confusion matrix.

Land Cover Change Detection

The method of using wavelengths to compare multi-data was applied (Skidmore, 2002). To detect the change between the two data sets the simplest approach of Huang et al. (1998) was used. Data were classified and labeled independently to get advantage of compensating for varied atmospheric and phonological condition between dates of even.

Soil Characterization

The study area is subdivided on physiographic basis into three landscape ecological zones (Figure 2); according to altitude and soil drainage: zone AA represent the undulating physiographic system, zone BB and zone CC were taken along the slope to represent the down and upper slope respectively. The soil at field level were grouped into two major soil types Clay (gray to black) and Gardud soils (Brown to reddish brown) based on soil particle size distribution and their colours. Sub-major soil types Gravely Clay, Gravely Gardud, Red Gardud and Stony to Gravely soil were characterized. The vegetation cover types (Dense, Medium, light, Fallow and Bares soil) are considered for each soil type.

Collected samples subjected to routine soil data analyses include; Laboratory preparation, Particle-Size Analysis by Sedimentation (Pipette method with an automatic particle size analyzer), Analysis of Total Carbon and Total Nitrogen.(a tin capsule solid sample is placed under a helium stream in an oven at 850°C. Injection of oxygen causes a very brief rise in temperature (1800°C) and total combustion. The respective C and N contents are measured by gas chromatography), Determination of Carbonate Content in Soils (Volumetric method),. Analysis of the Cation Exchange Capacity (CEC) (by the hexaminecobalt trichloride method using ICP spectrometry), pH (Measurement is performed with a combined glass electrode in a 1:2.5 (M/V) soil suspension), Measurement of the Electrical Conductivity of a Solution (Measurements are performed using a conductivity meter with direct reading on the scale selected. The apparatus is calibrated using a 56 mg/l KCl solution whose conductivity is 100 µS/cm at 25°C.

The study covered a total area of about 250,000 ha. Representative soil samples (105) and soil profiles were described using the FAO guidelines for soil description (FAO, 1990), and sampled by genetic horizon. Each sample was a bulked composite of three sub-samples taken with auger in diagonal basis. Subjectively the samples were collected to represent both soil type and land cover. The geographic coordinates of each sampling point were recorded using the Global Positioning Systems (GPS).The elevation of each sampling point was recorded from a geo-referenced-interpolated contour map of the area (scale 1:250 000). All the soil samples were analyzed in the Soil laboratories at Institute of Soil Science and Site Ecology, TU Dresden using procedures of soil

analysis described in DIN Deutsche Institut für Normung e.v.

Results and Discussion

Land Cover Mapping

The result (Figure 3) has indicated that; cultivated area (Bare and Fallow) is the biggest followed by Light Forest (LF) land and Dense Forest (DF) land use/covers. Medium Forest (MF) is only covered 6% of the study area.

Accuracy Assessment

Accuracy assessment showed that the overall accuracy is about 64.54% and the kappa coefficient is 0.63. The Kappa value indicates that the accuracy of the supervised image classification using Maximum Likelihood Classification is 63% better than doing it randomly or using unsupervised method. The overall accuracy obtained is relatively better compared to Pereira (2004) findings in Mozambique (about 53%) for eight land use/covers using ASTER imagery. Marcal et al. (2005) found classification accuracies ranging from 44.6% to 72.2% using different classifiers of ASTER data in Portugal. While accuracy reported by Aynekulu et.al(2008),in Ethiopia reached 80%. No sensitivity analyses was done for the accuracy and it was assumed that the ground truth for the different land use/covers is absolutely correct as stated by Mann and Rothely,(2006). Generally, the classification accuracy found in this study is looked acceptable to map land cover as a base for monitoring and management in the study area where data is scarce, with focusing on other classification techniques. Relatively low classification accuracy in this study might be due to difficulties of having no distinct delineation between classes.

Approaches of classification depending on vegetation species might introduce a better classification accuracy as well as using more than on techniques will support the accuracy result.

As indicated in Table 1, the medium forest classes (MF) were classified with higher use (75%) and produces (75%) accuracies. This is might be due to the characteristics of Ficus species, which were relatively broad leaves types in regard to the rest Acacia spp. In other hand there is some spectral signature overlap among the cultivated, LF and DF lands. The mixture is partly due to the open canopies of the shrub and grasses. Moreover, the dominate tree species that covers large parts of the study site is Acacia species that have tiny leaves which might not give clear spectral signature for ASTER optical sensors. The spectral signature of the cultivated lands is also mixed mainly with grass of Fallow land (FF).

Land Use/Cover Status: Soil Adjusted Vegetation Index (SAVI)

Figure (4) shows change and no change happened with the time span from 1986 to 1999 and from 1999 to 2005. The result deduced that, late 5 year span from 1999 to 2005 experienced drastic land use/ cover changes. Dark colour means highly affected spots. Changes taken place in the Northeast the study area are noticeable. The Soil Adjusted Vegetation Index (SAVI) was implemented as a best model to identify land use and cover in relative dry grass land. The visual differences of the land use/ cover were clearly depicted in (Figure 5). Vegetation covers showed severe fragmentation in 2005 image in compare to image 1999 and image 1986 respectively, indicating serious vegetation degradation with time as well as human pressure. More than 87,000 ha were lost in the last two

decades with average loss of about 1.8% per year. The result is strong sign to the environmental degradation that taking place in the study area and in the Sudan as well, particularly the soil erosion that would be enhanced at vegetation loss (Hill et al 1995a). Atta El Moula, (1985) and UNEP report, (2007) declared that Sudan's deforestation rate of natural forests was closed to 2% per year which has been emphasized by this study 1.8%.

Land Covers Changes Detection

The land covers changes were then detected as it shown in (figure 6a,b).

The cultivated land (BF+FF) was proliferated three times in the last two decades. It was increased from 10% in 1986 to 20% in 1999 and to 40% in 2005. In other words the change that happened in the last

5years is equal two times the changes in previous 15years. The non- cultivated (DF, MF and LF) or forest land was reduced by 38%, from 79% in 1999 to 49% in 2005.

Soil Dynamic Response to Land use/cover

The soil dynamic response to LU/LC was measured in reference to virgin soil under the Dense Forest in both clayey and Gardud soils. The results (Figures 7a,b)revealed that, there was a considerable variation between soil variables and between soils as well.

The soil physical parameters were affected considerably when compared to the chemical ones. As well as the Red soils (Gardud soils) were relatively more affected than the Dark clayey soils. Gardud soils are vulnerable to rain drops detachment and transportation as stated by (Elgubshaw,1995).

Table.1 Accuracy Assessment (Confusion Matrix)

Classified data	Reference data					User's accuracy
	DF	MF	LF	FF	BF	
DF	66.71	0.53	8.34	8.95	12.86	43
MF	3.49	56.87	21.81	0.55	13.84	75
LF	17.99	13.65	48	5.81	13.73	40
FF	6.14	0.56	0.73	84.68	6.6	60
BF	13.97	11.41	8.69	12.33	52.31	50
Producer's accuracy	60	75	50	50	40	

Fig.1 The Study Area Location and Elevation Characteristics

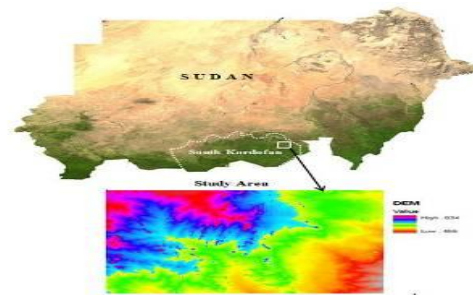


Figure.2 Physiographic Map Showing Location of (Aa, Bb And Cc) Areas and Samples Spatial Distribution Pattern

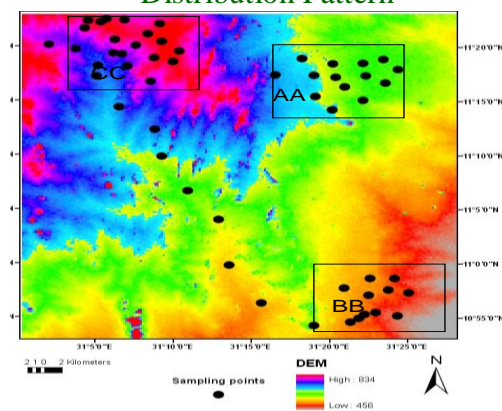


Figure.3 Show Land Cover Types and their Percentage

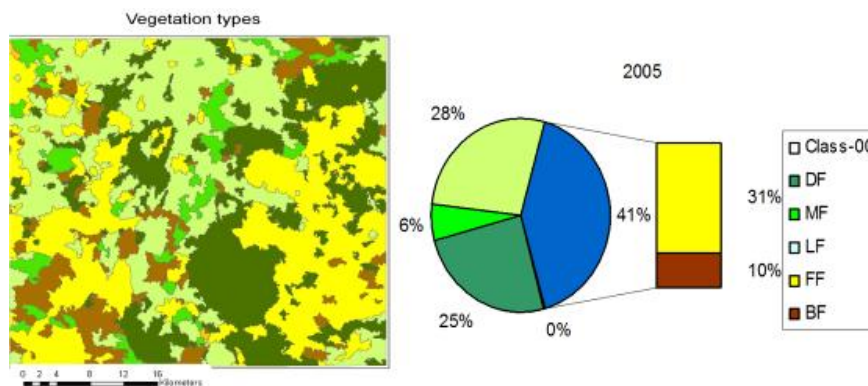


Figure.4 Changed and No Changed within the Study Site

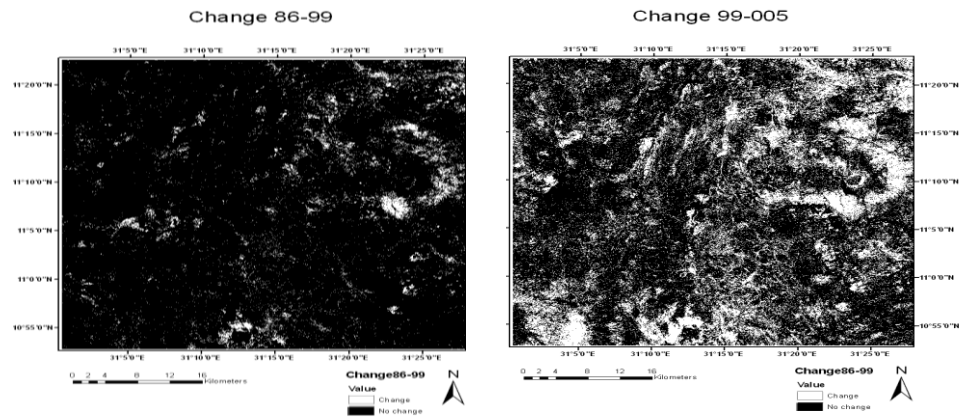


Figure.5 Land use/ Cover Detection using SAVI

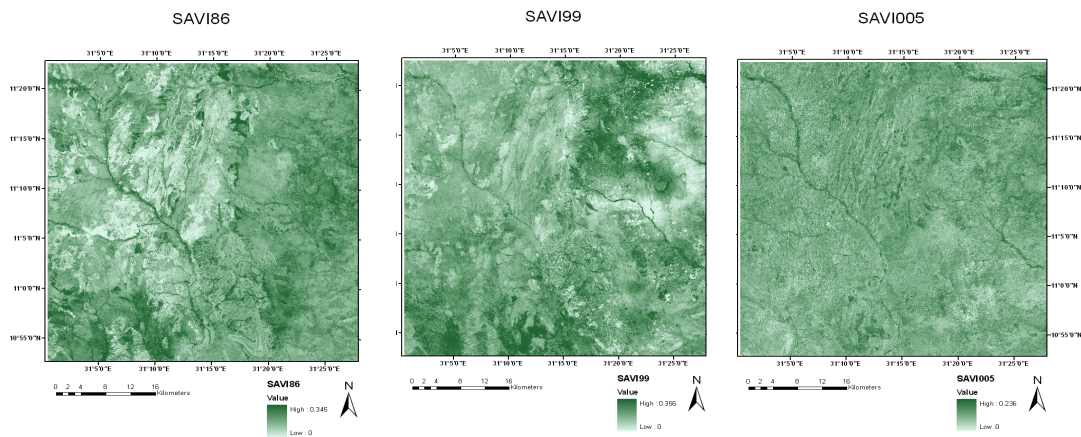


Figure.6a Land Use/ Land Cover

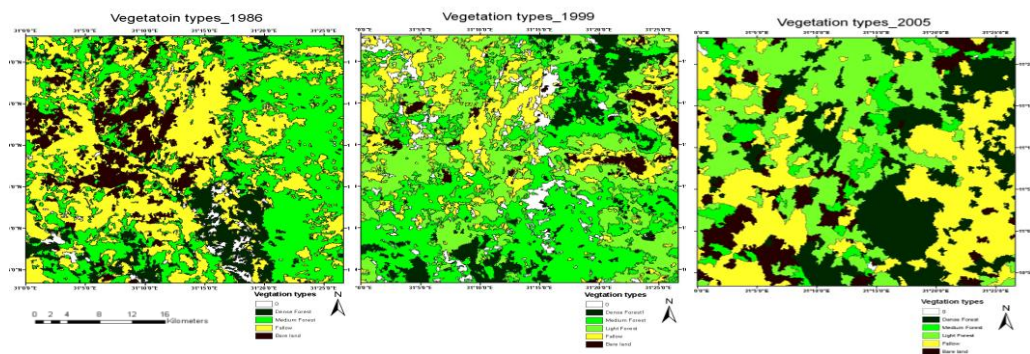


Figure.6b Land Use/ Cover Types and %

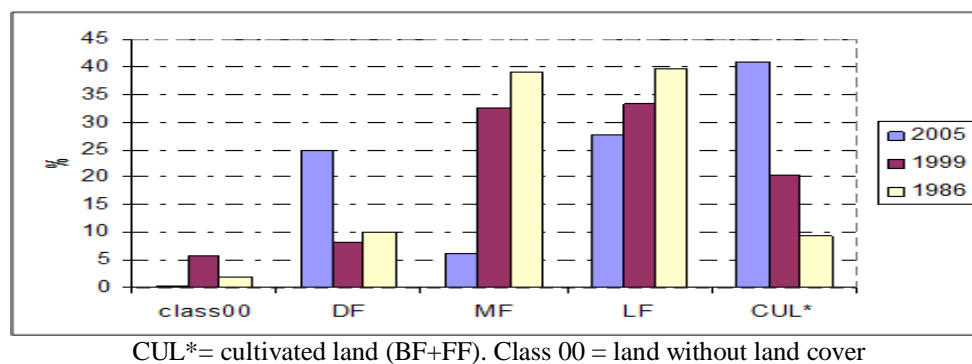


Figure.7a,b Soil Properties of Two Soil Types at Different Vegetation Cover

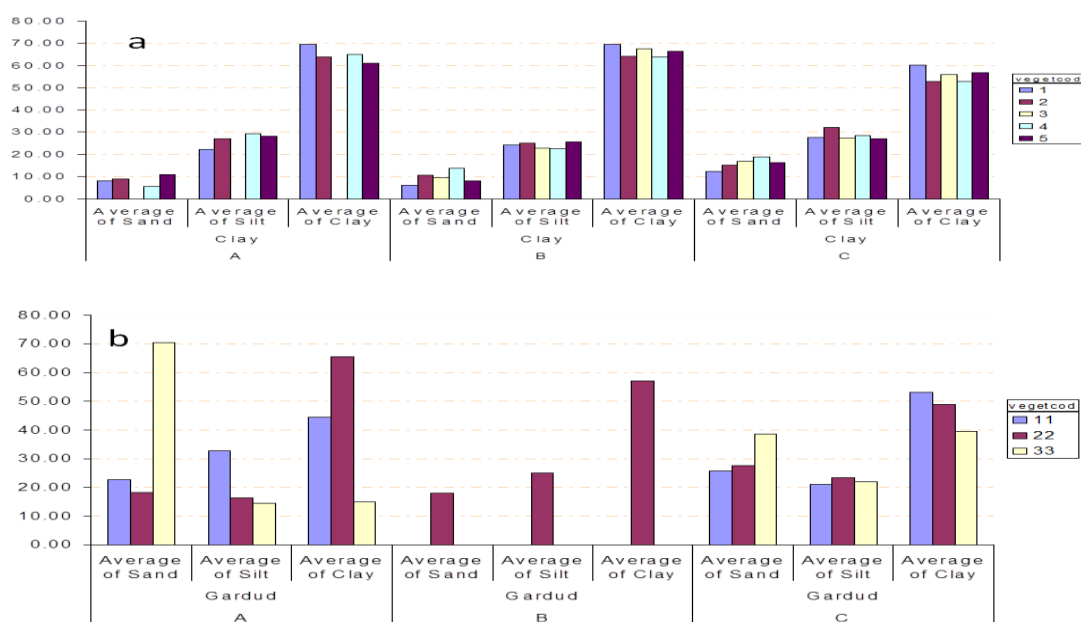
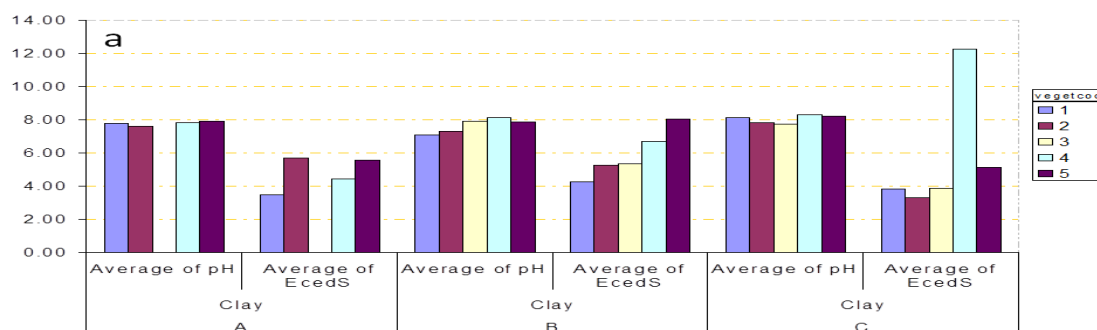
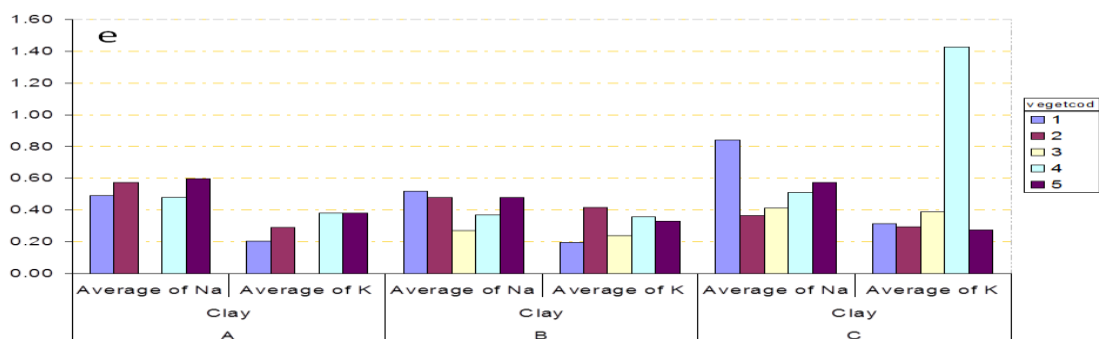
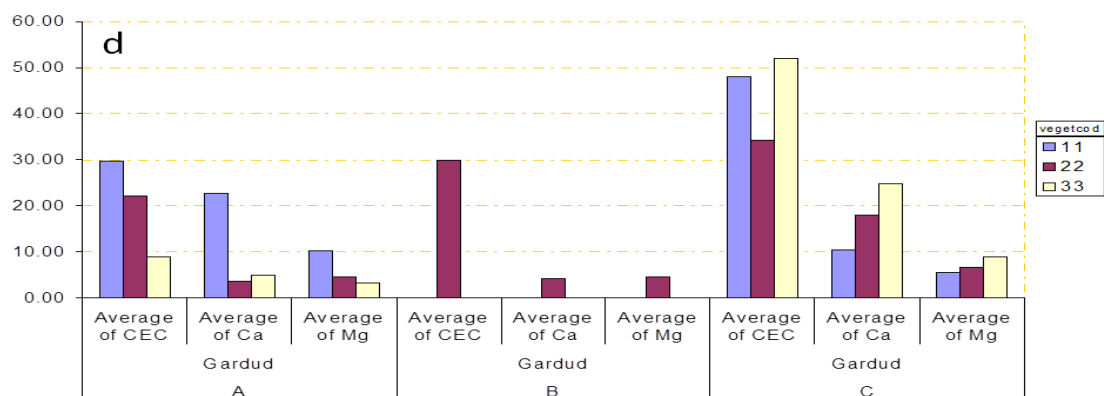
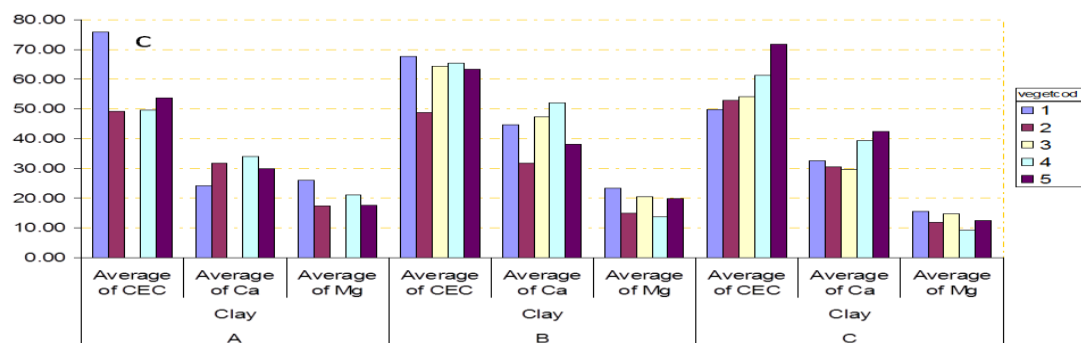
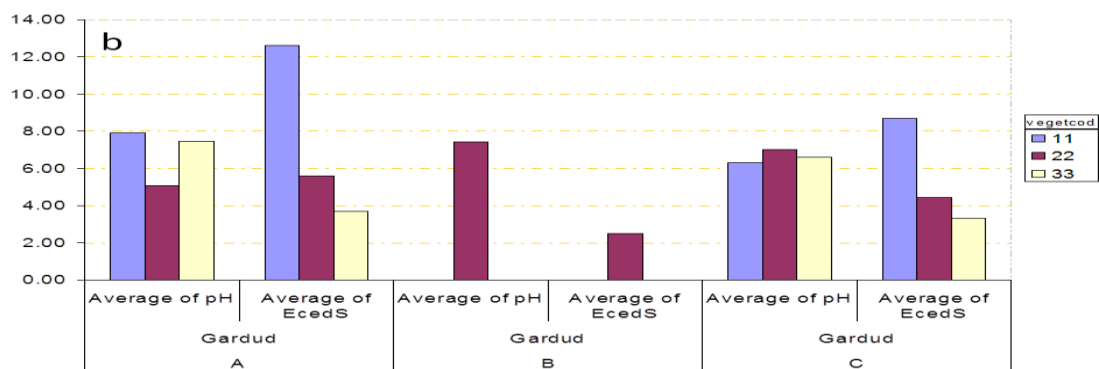
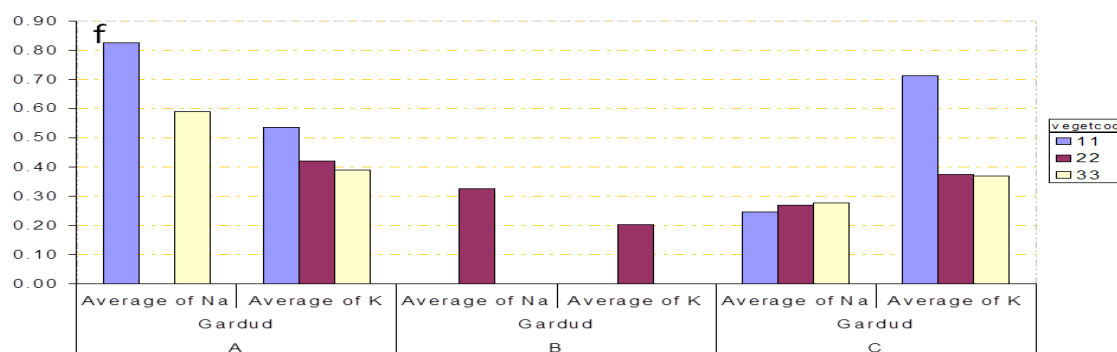


Figure.8a,b,c,d,e and f Soil Parameters as Affected by Soil Type, Vegetation Cover and Position







*1/ 11=Dense forest (DF); 2/ 22=medium forest (MF); 3/ 33 =light forest (LF); 4 =fallow (FF) and 5= bare (cultivated) soil (BF).

**A= undulating, B= down slope and C= upper slope positions

The soil structure and texture in both the Red soils (Gardud) and the Dark clayey soils were affected positively with vegetation cover. Top soil structure of Light forest (L.F) as exposed to long term of grazing and as nomads temporary settlement have been differed when compared to virgin soil under the Dense Forest (DF).The texture results were emphasized that the top soil of the Light Forest was prone to loss of fine grains, most properly due to soil erosion.

Deterioration of soil structure is overriding and more general form of soil physical deterioration that necessitates the importance of taking any changes in the soil structure very seriously. High degree of interaction between the different physical, biological and chemical factors and processes involved might hide soil physical degradation. Salinity (EC), Cation Exchange Capacity (CEC), Exchangeable basis, TN, and OC were revealed different levels of dynamic (Fig.8a,b,c,d,e and f).The Gardud soils have low fertility level;Salinity, Exchangeable basis(Ca, Mg, K, Na),TN and OC were decreased at the LF soil deducing the prone of these soils to erosion process. The Dark clayey soils (Vertisols) are deep (2-6m), fertile and less depleted. These soils are totaling 12 million ha out of 70 million ha of vertisols soils of the Sudan. According to Ayoub (2001) .The Dark

clayey soils in south Kordofan were existed in situ of basaltic parent materials, belong to two soil series, Elbardab (Grayish brown) and Dameik (Dark grayish brown) as stated by Eissa (1980).

The findings agreed with Ayoub (2001) and Eissa (1980). These soils are chemically rich, nevertheless they recorded a little bit less values for the CEC (49-54), a little bit high O.M (0.5-1.5%), and non-saline soil. The TN% is very low at all findings. The difference between results most properly attributed to the methods used. At a time that the result indicating no or subtle variation between the soils under different land use systems, the appreciable presence of gravel on the surface of these soils stand as an evidence of water erosion. But soil depletion or soil changes may have been hidden by the profile thickness and relatively high fertility levels. I am afraid to discover these facts at died time where resilience become too late.

In conclusion, in South Kordofan area civil war started at rich savannah areas which are usually the settlement areas for the nomads and pastoralists moving from the north during summer. Due to war these movements are restricted and pastoralists are obstructed at poor savannah areas at the northern parts of South Kordofan including

the study area. As well, the displaced rural population (villagers) at war zone are bound to move to safe haven areas at the north. These entire exodus end up at Abu Jubeiha area and some other few areas in northern parts of South Kordofan. These large settlements of population with their livestock create tremendous pressure on the already fragile environmental resources at Abu Jubeiha area.

Evident signs of environmental degradation are taking place in the study area. Serious vegetation degradation was documented. Vegetation loss average is about 1.8% per year. Palatable grasses were replaced by less palatable plant species and a considerable variable decrease in tree density was also noticed.

Soils are chemically rich and are non-saline. Evidence of water erosion is noticed. Depletion or soil changes may have been hidden by the profile thickness and relatively high fertility levels.

Recommendation

1. Widespread and rapidly accelerating environmental degradation is urgently needed to be addressed. It's one of the most driving forces of local civil wars in great Kordofan and elsewhere in the country that resulted in displacement of rural population, nomads and their animals. According to the Sudanpost-conflict environmental assessment report, there are five million internally displaced people and refugees in Sudan.
2. Investment in environmental management financed by the international community and from the country's emerging boom in oil, minerals and gas exports will be a vital part of the building efforts that sustain the

environment, natural resources and peace.

3. More research is required to locate degraded areas and identify degradation processes.
4. Remote sensing/ GIS techniques should be introduced in change detection applications and since their advantages and usefulness were proved in land degradation studies.
5. Rural development and rangeland management program should be initiated in degraded areas.

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