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Applying Remote Sensing Tools for Assessing Desertification Process within the Agrosilvopastoral System, North Kordofan- Sudan

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Abstract:

North Kordofan State is located in central area of the gum-belt across Sudan. More than 80% of the state population depends on subsistence rain-fed farming, gum arbic production and animal herding activities together with traditional gold mining. Agrosilvopastoral system is considered as one of the leading farming sectors in the state. Semi-arid climate dominates the area of the state and makes it vulnerable to land degradation and desertification risks. Erratic rainfall varies significantly in distribution and timing, thereby magnifying the risks of crops failure. Irrational land-use practices in terms of destructive shifting cultivation, forest degradation, removal of vegetation cover and overgrazing have led to drastic change and transformation in the farming system components. Therefore, the objective of this paper is to screen and assess the impacts of desertification process within the agrosilvopastoral system in the area by using remote sensing and GIS tools in relation to some socioeconomic and human factors. After clarifying the main concepts, indicators and modules, the remote sensing and GIS tools were applied for the purpose of the study. Historical records in terms of some variables such as rainfall, crop yields, and animal and human population were used in association with the remotely sensed data. The results showed that the agrosilvopastoral system in the area is significantly susceptible to land degradation and desertification risks. This was reflected by significant increasing in bare-lands coupled with sharp decreasing in crops productivity as moving from south to north in the study area. Furthermore, land cover change has occurred rapidly and occupied large areas, especially in the western part of Bara locality, which constitutes the most vulnerable one pertaining to the desertification process. The cases covered by the paper gave strong arguments that link the process and drivers of desertification to the change and transformation within the agrosilvopastoral system. Understanding dynamics and nature of this change/transformation is essential to setup an efficient land use strategies for resilience of the agrosilvopastoral system against crisis.

(Keywords: agrosilvopastoral system, change and transformation, remote sensing and GIS tools)

Introduction:

Agrosilvopastoral system of land use comprises growing of field crops, tree and pasture/ animals in the same unit of land; a subdivision of agroforestry. The system plays a key role in employment and output generation in North Kordofan State, Sudan. It contributes to one third of the cash crops at the national level (NKSMF, 2012) *viz.* water melon seeds (70%), roselle (65%), camels (30%), desert sheep (17%) and gum arabic (50%). Despite those favourable estimates, the substantial untapped potential of the sector is mainly due to the fragile ecosystem that makes the regions more vulnerable

to land degradation and desertification risks (Zakieldeen, 2009). Recently, climate changes, successive droughts, population pressure and chronic food shortage in the study area forced farmers to change the bush fallow rotation system, by expanding years of cropping patterns at the expense of fallow rotation (NKSCI, 2012). This resulted in wind erosion and loss of soil fertility, along with reduction of crop yields. Furthermore, the increase of livestock population coupled with shrinking of pastoral lands and overgrazing affects severely productivity of agricultural lands (Weber & Stoney, 1986). However, the push fallow rotational system which was intensively practiced in the past in North Kordofan area doesn't strongly exist nowadays.

Objective:

The general objective of this paper is to highlight land cover/land use change within the agrosilvopastoral system in North Kordofan state. Specifically, it was aimed to screen and assess the impacts of desertification process within the system by applying of remote sensing and GIS tools in relation to some socioeconomic and human factors.

Study Area:

Despite the dominance of the agrosilvopastoral system over vast areas in North Kordofan state, the study area was selected from western part of Bara locality (Figure 1). This is mainly due to the existing of clear components of the agrosilvopastoral system. The area is extremely vulnerable to land degradation and desertification risks. In addition to that, availability of technical data required for applying remote sensing and GIS tools. The region lies within the semi-arid zone with limited seasonal rains (150- 350mm). The rainy season is from June to October. The soils are varied, with sand plains (gozland) making it suitable for grazing lands and growing of millet, watermelon, sesame and *Acacia* trees. Mobile whitish sand is found in forms of sheets and dunes. Clay depressions are found between the sand dunes. Most of population in the area are either subsistent farmers or animal herders.

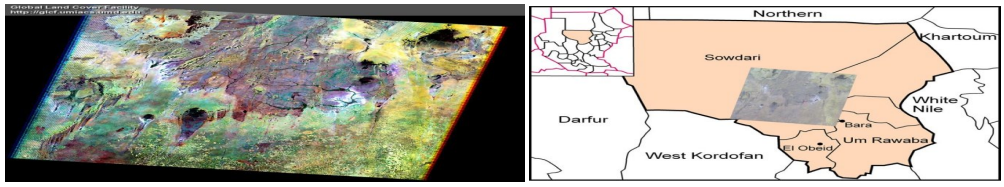


Figure 1: Landsat ETM 2005 of the study area *Source: Kheiry, 2007*

Materials and Methods:

The methodological aspects depended heavily on gathering and analyzing the remotely sensed data together with environmental and socioeconomic variables that obtained from the area. The records of rainfall, crop yield, and animal and human population were collected. Satellite imageries were analyzed qualitatively and qualitatively (analyzed by ERDAS Imagine software- Fix 11.0.5 version 2011). The combination of post classification methods and NDVI (Normalized Difference Vegetation Index) techniques were used. The steps were given below:

- ***Selection of the satellite imagery:*** Two cloud free Landsat TM and ETM scenes for the study area (acquired in October 1987 and November 2005, respectively) were selected for analysis. For both TM (5 Landsat) and ETM (7 Landsat) scenes, 7and 9 spectral bands (μ m) with ground resolution of 30 x 30 meters were obtained simultaneously. The TM spectral bands were distinguished into 7 categories {blue (0.45-0.52), green (0.52-0.60), red (0.63-0.69), near IR (0.76-0.90), mid IR (1.55-1.75), mid IR2 (2.08-2.35) and thermal (10.4-12.5)}.

- ***Analyzing remote sensing images:*** Firstly, a digital image processing was done by sampling and quantizing the numeric representation of the scenes through revolving and increasing spectral separability of the objects on the image. Secondly, image rectification and restoration was done to correct the distorted or degraded image. Thus, the two digital images were geometrically corrected using geo- referencing so-called ground control point with known co-ordinates to the corresponding pixels in the images. Thirdly, image enhancement on both scenes (1987 and 2005) was performed.
- ***Information extraction:*** Information has been extracted from the two satellite images and the Normalized Difference Vegetation Index (NDVI) was calculated.
- ***Images classification:*** This was done to categorize all pixels in an image into land cover classes or themes. This is either supervised or unsupervised classification. This study used unsupervised classification with combination of three bands (5, 4 and 3).

Results and Discussion:

The analysis showed that rainfall, as one of the key resources in the study area, is characterized by patterns of fluctuated, depleted and erratic trend. This is clear from the historical (1960-2005) records of rainfall at Bara, Elobeid and Sodari (Figure 2) regions.

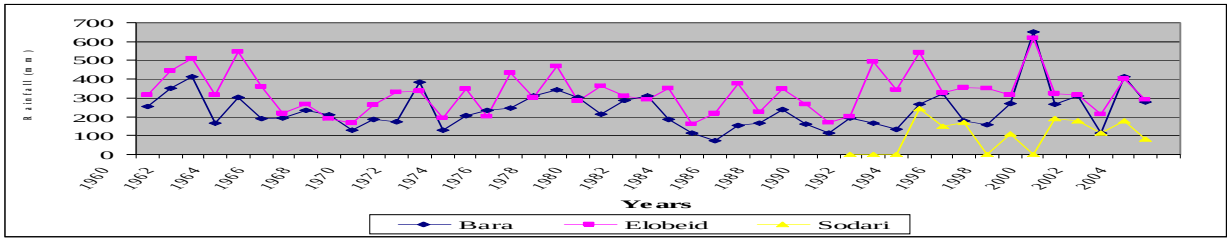
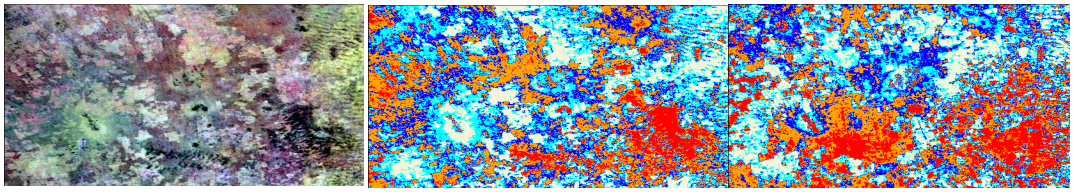


Figure (2): Rainfall at Bara, Elobeid and Sodari regions (1060-2005) *Source: Kheiry, 2007*

Rainfall depletion has been most severe in the western part of Bara locality, where the moving average of annual rainfall between 1960s and 1980s revealed a decline trend by 20 %, length of wet season has contracted and rainfall zones have migrated slightly southwards (Kheiry, 2007). For mapping land cover change in the study area, two classified (unsupervised) maps (Figure 3) were produced for the intended period (1987 and 2005) to show the extent of that change.



Landsat TM (1987) Classified map (1987) Classified map (2005)

Unclassified	Grazing lands	Mixed trees/shrubs on sand soil
Rain fed agriculture1	Rain fed agricturature2 (scattered)	Mixed trees/shrubs on clay soil

Figure 3: Two Classified maps (1987-2005) for the study area (derived mainly for this paper)

Then, the two maps were expressed statistically by producing different classes of land cover/land use as shown in Figure (4). Accordingly, several results could be obtained from interpretation of these classes as moving from 1987 to 2005:

- The area of the first class (grazing lands) showed a significant increase over the period by 88%. This increase in pastures happens, most likely, at expense of crop lands and forests. Estimates of

the Natural Resource Development Project of Western Sudan, cited in FAO (2005), showed that the average annual growth rates of sheep, goats and camels in Sudan were 7.6%, 10.1%, and 1.8%, respectively. The data also revealed that growth rate of livestock population in the area is relatively high (6%) compared with the growth rate of human population (3%). Accordingly, the increase in livestock population over the whole period (1987-2005) is equivalent to 108% which is relatively high than the responding increase in pastures (88%). This, coupled with overgrazing, has affected severely soil fertility and led to poor productivity of agricultural crops in the area. NKSMAW (2008) indicated that average productivity of millet, sorghum and watermelon seeds in Bara locality in season 2006/07 was 0.087 ton/hectare (60% less if compared to the year 1980). This also indicates the drastic change in agrosilvopastoral system potentials.

- The second class (mixture of trees and shrubs on sand soils) exhibited a decrease (-8.3%) over the period, which implies removal of shrubs and trees from the agricultural lands. The same results (-8%) were obtained from the assessing the third class (mix trees and shrubs on clay soils). Removal and unplanned burning of shrubs and *Acacia* trees for wood and shifting cultivation, which is very common in Bara locality, destroy the soil cover, and leave it bare and hence vulnerable to erosion and desertification.
- The forth class (rain-fed agriculture 1), revealed a decrease (-12.5) in the total area cultivated with millet, sorghum, sesame and watermelon, while the fifth class (rain-fed agriculture 2) remained unchanged. The reduction in areas of rain-fed of agriculture or shifting cultivation is mainly due to increasing livestock populations and pressure on cultivable and grazing lands, and the elimination or declining of fallow rotation period. Accordingly, these irrational land use patterns aggravate the problem and lead to land degradation and desertification risks.

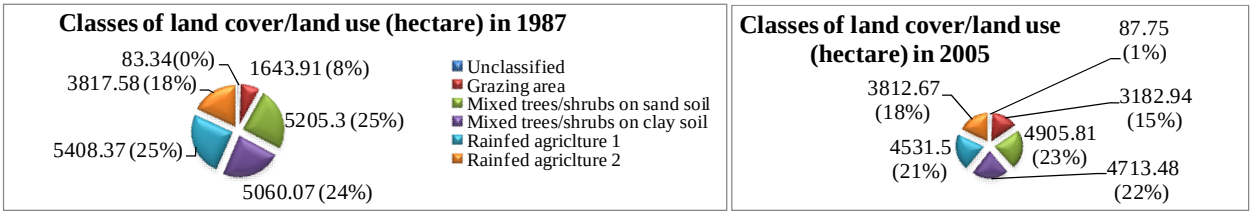


Figure (4): Distribution of land cover/ land use classes in the study area

Conclusions and Outlook:

The paper gave strong arguments that link the process of desertification in North Kordofan to the land cover change within the agrosilvopastoral system. Application of remote sensing and GIS for screening and assessing desertification needs powerful networking with different institutions and organizations and capacity building and sharing of information.

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