Tropentag 2010
ETH Zurich, September 14 - 16, 2010
Conference on International Research on Food Security, Natural Resource Management and Rural Development

Mapping and Assessment of Sand Encroachment on the Nile River Northern Sudan, by Means of Remote Sensing and GIS

E. M. Eljack[1, 2*], E. Csaplovics[1], H. E. Adam[1, 3]

[1]Technical University of Dresden, Institute of Photogrammetry and Remote Sensing, Germany.
[2]Universityof Khartoum, Faculty of Agriculture, Dep. of soil and Environment Sciences, Sudan.
[3]University of Kordofan, Faculty of Natural Resources, Forestry and Range Department, Sudan.

Introduction

The problem of sand encroachment and their environmental impact on the Nile River morphology represents great concern. Attention was drawn to the problem since early sixties and was again renewed during the workshop on water resources development organized by UCWR in the Northern State, Sudan, held at Dongola during October 2000 when a resolution was taken to follow up the problem.

The Nile River is one of the largest, longest, and most remarkable rivers of the world, since it flows in its voyage northwards from the sources in the South, near Lake Tana, up to its mouth at the Mediterranean Sea. Its course traverses through countries: Burundi, Zaire, Rwanda, Tanzania, Kenya, Uganda, Ethiopia, Eritrea, Sudan, and Egypt. In addition, it contains lake Victoria, the largest freshwater in the Eastern Hemisphere, Ruwenzori Mountain (512m), the third highest mountain in Africa, and Cairo, the largest city in Africa (UCWR, 2001). The Nile River provides life and prosperity to the countries along its course. Sudan and the Nile River system have a special relationship. On one hand, more than 70% of Sudan falls within the Nile basin. Being the source of life, about 85% of the population depends on the river. The Blue Nile basin has the highest concentration of people, followed by the White Nile, the Main Nile and the Atbara River. Even though 10 countries share the Nile, 63% of the basin areas lie within Sudan’s border, and the main Nile tributaries meet inside the country. The Nile leaves Sudan as a single artery through the Sahara Desert on its way to Egypt and Mediterranean. Sudan is a source, a path and drainage basin for the Nile (Hamad and El-Battahani, 2005).

Usually natural rivers are exposed to morphological changes due to a lot of factors, which could be internal or external ones. One of the external factors is the sand encroachment. Sand encroachment is a problem that relates directly to the requirements and life basin downstream countries, Sudan and Egypt. The moving of sand of different sizes (fine and medium) occupies great areas of the banks of the Nile River system. North of latitude 13° N, the Nile and its branches the White and Blue are greatly influenced by sand encroachment. The affected areas along the Nile and its tributaries the Blue and White Niles are the northern parts of Gezira State, the northern parts of the White Nile State and then very large areas in the River Nile State.

* Contact addresses: Eljack, Elmuiz Mohammedsaeed Gerokstr. 38/1101, 01307 Dresden, Germany.
E-Mail: elmuizeljack@yahoo.com

Sand dunes threaten to bury human settlement, roads, farms, water and other resources. They have a fragile environment where instability with a series of changes in the structure and dynamics lead to a system not in equilibrium with its surroundings within an arid and hyper- arid climates changes characterized by increase of evaporation and long periods of dryness, very low rainfall and vegetation. The phenomenon of morphological changes manifested in river meandering, sediment deposition, bed aggradations and bank erosion including sand encroachment have been noticed since the sixties, while yearly expanding in a slow process. The wind blown sand and its consequent creep to the river channel have contributed to a large extent to gradual morphological changes. These morphological changes will have serious impact on the region of the Nile River system, particularly Sudan and Egypt. An example is the adverse impacts on the economic and agricultural activities, a matter that was quite felt in the day- to-day lives of the peoples in theses area (UCWR, 2001).

The use of remote sensing and GIS techniques over the past several decades as a tool to study dynamic features such as sand dunes has given the researchers a synoptic view of the entire field as well as it sources. In addition, the ability to examine changes over time allows for the extrapolation of current climate regimes and the monitoring of marginal areas susceptible to future desertification (Ramsey, 2003).

One location of wind deposition, directly along the course of the Nile River is in north-central Sudan. Here, in the Dongola- Merowe region, understanding the dune movement is vital for mitigating the potential sand threat to the Nile River. Thus, the goal of this study is to estimate sand dune movement or encroachment in the region by means of remote sensing, using three landsat images, acquired roughly 15 years apart and spanning a time period of 27 years.

Material and Methods

The study was conducted in (Kannar area) in Northern State, Sudan on the eastern bank of the Nile River approximately midway between Kareima and Eddaba where the Nile River flows in an east-west direction before it resumes its journey to north. The area is approximately parallel to the Nile with the exception of a small portion in the eastern part of the area which is tilted to the north- east. Nile River is bordering the area from the south. The area is at the right angle to the prevailing north and northeast wind, so the area is subjected to severe wind. Extensive sand sheets intermingle with mobile barchans dunes and several other types of dunes. In addition, there are elevated alluvial soils (middle and high terraces of the Nile River) with various degrees of elevation and of varying thickness. Some shifting sand dunes and sandy hummocks are encountered in some places in the study area. The main geological formations in the area are Basement complex, Nubian formation, Volcanic intrusive and the superficial deposits (Whiteman, 1971). Aeolian stabilized sand dunes and sand sheets are as well encountered in the study area. According to Van der Kevie (1976) the study area falls in an arid climate (summer rains and cool winters).

The rain fall is erratic in quantity, intensity and distribution. The area falls under the effect of northerly winds in October through May and southwesterly winds as from late June through October. The high temperature coupled with strong solar radiation result in values of potential evapotranspiration exceeding by far the rainfall almost throughout the year, except in August, a phenomenon common to the arid climate, which typifies the study area.

The study area lies with the desert ecological zone of Sudan with space vegetation where there are pockets of vegetative cover on the high terraces, desert plains and the wadis. The dominant species are Salam (*Acacia ehrenberiana*) often associated with sand hummocks on which Tarfa (*Tamarix articulate*); Marrekh (*Leptadenia pyrotchnica*), Tundub (*Capparis deciduas*) and Miskeet (*Prosopis juliflora*). Scattered settlements were found in the study area. There are some villages along the Nile River (e.g. Gilas, El- Nafaab, El-Rekabia, Mora, El-Taker, El-Sidir, Kuri and El-Hau). A significant proportion of the inhabitants of these villages are engaged in agriculture along the daily needs for their local community.

Data acquisition

Three cloud free landsat MSS, TM and ETM+ scenes covering the study area were selected for analysis. These images data were acquired (from the Global Land Cover Facility (GLCF) at University of Maryland) in dry season in September 1972, October 1987 and October 2001 for the study area. MSS image consist of four bands. TM and ETM+ imagery was acquired in seven and nine bands respectively, they covering the visible, near and middle infrared region of the electromagnetic spectrum. An extensive field survey was performed throughout the study area using Global Positioning System (GPS) equipment. This survey was performed in order to obtain accurate location point data for each land cover class included in the classification scheme as well as for the creation of training sites and for signature generation; in addition, creating an independent data set reserved for accuracy assessment.

Image processing

Preprocessing commonly comprises of sequential operations, including atmospheric correction or normalization, image registration, and masking (e.g., for cloud, water, irrelevant features) (Coppin and Beuer, 1996). The two images, MSS 1972 and TM 1987, were geometrically co-registered to the rectified ETM+ 2001 data (UTM north zone 36). Georeferencing was provided by selecting and applying ground control points (GCPs). Nearest-neighbour re-sampling technique was used. The root mean square (RMS) error of georferencing is approximate 0.5 pixels. Subsets of the study area were selected. Effective classification of remote sensing image data depends upon separating land cover types of interest into sets of spectral classes (signatures) that represent the data in a form suited to the particular classifier algorithm used (Richard and Kelly, 1984). Supervised classification processes involve the initial selection of areas (training sites) on the image which represent specific land classes to be mapped (Robinove, 1981). All training sites were utilized in the generation of signatures required for supervised maximum likelihood classification. Supervised maximum likelihood classifier uses the Gaussian threshold stored in each class signature to determine if a given pixel falls within class or not.

Change detection analysis

Change detection is the process of identifying differences of an object or phenomenon by observing it at different times (Singh, 1989). The basic premise in using remote sensing data for change detection is that changes in land covers result in changes in radiance values which can be remotely sensed. All digital change detection is affected by spatial, spectral, temporal, and thematic constrains. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the change. The selection of the appropriate method therefore takes on considerable significance. In order to identify changes in different land cover in the study area change detection was adopted using post-classification.

Results and Discussion

The main source of information to assess the status of sand encroachment in the study area was based on remote sensing data analysis and interpretation. Supervised classification was performed on ETM+ (2001), TM (1987) and MSS (197), to identify and map six main units (classes) as follow and shown in Figure (1): 1- water (The Nile River) 2- vegetation 3- alluvial soil (alluvial plain) 4- stabilized sand dunes 5- active dunes (mobile sand dunes) 6- mountain area.

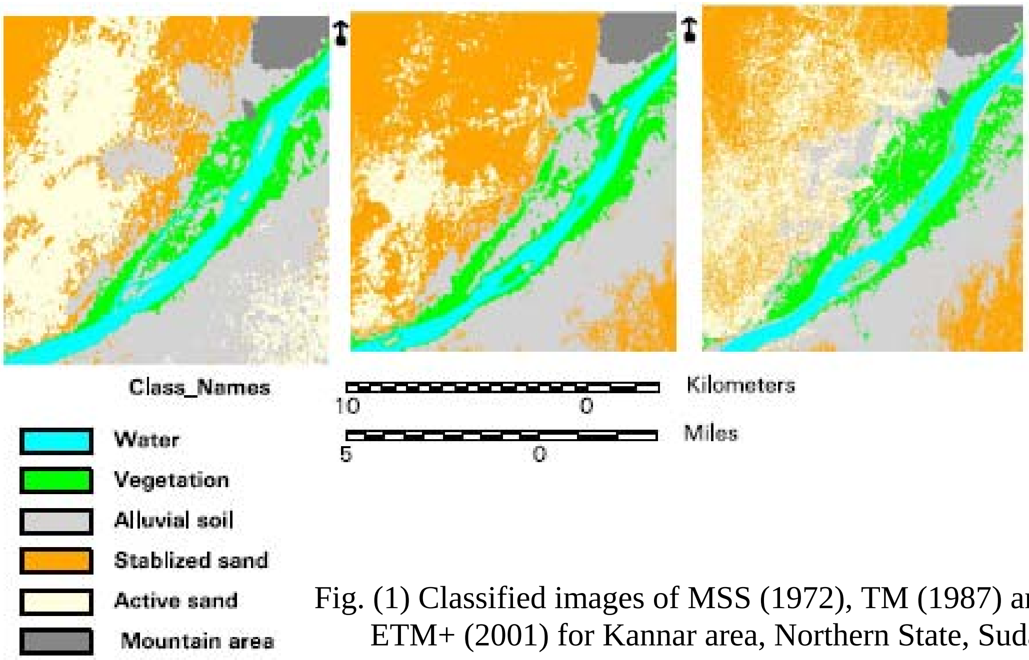

Fig. (1) Classified images of MSS (1972), TM (1987) and ETM+ (2001) for Kannar area, Northern State, Sudan

The north eastern area of the study area, which is a hilly region without sand dunes, was omitted from the present study and added as sixth class. From this interpretation it is possible to state that the sand moved from the northern and eastern part of the study area towards the Nile River and Kanner area. Sand movement is affected by the dominant direction of the prevailing wind (northeasterly wind in winter). Thus, the most Hazardous dunes are located to the northeast of the Nile River. The source areas for the dune fields are the very extensive areas of loose and shifting sand overlies the rock pavement. These hazards endanger the Nile River course by encroaching towards it, whilst the rest is expected to settle in the irrigated fields. The supervised classification results for ETM+ (2001) showed that the vegetation, stabilized sand dunes and active sand dunes covering 12%, 25.8% and 23.8% of the total area, respectively. While in TM and MSS vegetation, stabilized sand dunes and active sand dunes covering an area of (9.6% and 9.3%), (40.% 17.7%) and (12% and 29.9%), respectively (Table, 1).

Table (1) Distribution of land cover in 1972, 1987 and 2001 in Kannar area, Northern State, Sudan

Class Name	MSS (1972)		TM (1987)		ETM+ (2001)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Water	1198.63	7.98	917.84	06.11	1003.70	06.68
Vegetation	1393.47	9.28	1444.34	09.62	1805.96	12.02
Alluvial soil	4803.39	31.99	4311.99	28.72	4308.09	28.69
Stabilized sand	2664.50	17.74	6058.33	40.34	3872.16	25.79
Active sand	4496.92	29.94	1824.07	12.14	3566.67	23.75
Mountain area	458.67	03.05	458.67	03.05	458.67	03.05

The most dominant classes (stabilized sand dunes and active sand dunes), are collectively covered about 50% of the area in the three multi-temporal imageries. This attributed to the location of the study area in the Nubian Desert, which is characterized as primarily a rocky sand stone plateau with a poor and remote part of the Sahara. These findings were supported with the findings of Elhag, (2003). The decreased in area covered by sand dune (1987-2001) could be attributed to an increase in the area covered by Nile River course due to exceptionally high flood during the year 2000.

Conclusions and Outlook

The hyper-arid environment of the Northern State is worsened by the eminent danger of mobile sand sheets. Sand encroachment threatens the highly productive agricultural land and settlement in Kannar area. This will endanger the livelihood of inhabitants in this area. It is also clearly evident that the sand dune fields in the study area represent a threat to the course of the Nile River. Therefore, the study area is vulnerable to wind erosion. Hence it is the utmost important and urgency that increased emphasis on arresting sand dune encroachment through fixing existing dunes and preventing further sand encroachment by establishing physical and biological barriers to control moving sands. Empowering communities to initiate and manage land protection and economic activities establishment. Construction of the proposed canal starting from Merowe dam at the eastern side of the Nile River and up to Dongola province. Conduction of research aiming towards understanding the origin of encroaching sand and creation of new methods to prevent sand encroachment.

The integration of remote sensing and geographic information system (GIS) prove to be reliable tools to monitor the sand encroachment processes in many areas around the world as powerful and workable techniques and methodologies.

References

Coppin, P. & Bauer, M. (1996) Digital Change Detection in Forest Ecosystems with Remote Sensing Imagery. Remote Sensing Reviews. Vol.13, pp 207-234.

Elhag, A. M. H. (2003) Assessment of Sand Encroachment Using Remote Sensing and GIS: Case Study Dongola Area, Sudan. PhD. thesis, University of Khartoum, Sudan.

Hamad, O. E. and El-Battahani, A. (2005) Sudan and the Nile Basin. *Aquatic Science.* Vol. 67, pp 28 - 41.

Ramsey, M. S. (2003) Global Desert Monitoring With ASTER; Research Projects, IVIS Laboratory, University of Pittsburg.

Richard, J. A. & Kelly, D. J. (1984) On the Concept of Spectral Class. *International Journal of Remote Sensing.* Vol. 5. NO.6, pp 987-991.

Robinove, C.J. (1981) The logic of Multispectral Classification and Mapping of Land. *Remote Sensing of Environment.* Vol.11, pp 231-244.

Singh, A. (1989) Digital Change Detection Techniques Using Remotely Sensed Data. *International Journal of Remote Sensing.* Vol.10, NO.6, pp 989-1003.

Van der Kevie, W. (1976) Climatic Zones in the Sudan. Bulletin No. 27. Soil Survey Administration, Wad Medani, Sudan.

UNESCO Chair in Water Resources-Sudan, 2001 Report on Magnitude of Sand Encroachment on the Nile in Sudan. Khartoum, Sudan.

Whiteman, A. J. (1971) The Geology of Sudan Republic, Clarendon Press, Oxford, United Kingdom.