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Application of Remote Sensing and GIS to Detect Environmental Degradation in the Upper Basin of the River Atbara-Sudan

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Abstract

This study is an attempt to investigate environmental degradation through land use and land cover changes along the upper basin of the River Atbara in Sudan and their environmental consequences using remote sensing and the Geographical Information System (GIS) techniques. In order to achieve that, land use activities classified into seven categories (Table 1). Satellite images for the study area, in three different periods, were collected and analyzed to detect the changes in land use, and accordingly three maps of land use were produced (Maps No. 2,3 and 4), by using the computer soft ware ILWIS (International land and water Information System), as well as the previous maps of land use, three maps of land use changes were also produced (Maps No. 5,6 and 7). The changes in extent and percentage of the different land use categories were calculated for the different periods (1973,1986 and 1996) in (tables 2,3 and 4).

The investigation showed that, the area suffers from wide spread changes of land use especially in agricultural areas, forest and, rangelands. The mechanized rain-fed agriculture had expanded at the expense of rangelands and forests, that led to environmental degradation. by enhancing the soil erosion and consequently the crop yield declined sharply due to the decreased fertility between 1970-1990.

The investigation also revealed that, despite the shrinking of the rangelands area, the number of the grazing animals continued to increase. These simultaneous changes enhanced the degradation process in the area. Disappearing of some palatable vegetation species and, appearance of undesired species particularly at the north of the area was a good indication for environmental degradation.

Introduction

Sudan is much better than many other countries in its natural resources especially land stock, ownership and legislation are concerned. Its area is about 1.8 million square kilometers, helped with the low population density, and provides the rare chance for both adequate and balanced land-use plans for grazing, farming, woodlands and forests, as well as rural and urban settlements (Abdel Ati, 2002).

Yet land-use planning and management have not always made good use of that favorable and hardly-matched situation, with many negative environmental consequences both at the national and local levels. Like most developing countries Sudan's economy depends largely on agriculture, about 70% of the country's Population are economically active, in agricultural sector, and about 90% of them live in rural areas. Thus, it can safely be stated that rural development necessitates sustainable agricultural development, which is important for rural people. To achieve the goal of sustainable agricultural development, priority must be given to maintain and improve capacity of agricultural land with high potential to enable it to support the expanding population. However, conserving and rehabilitating land and other natural resources with lower potential in order to maintain sustainable man/land ratio is also necessary.

Soil degradation is the most important environmental issue facing the Sudan. Most forms of environmental degradation are natural processes accelerated by human activities, particularly over-cultivation, over grazing, and deforestation, which increase the water runoff and consequently accelerates soil loss and cause land degradation. Multi-dates aerial photographs and/or satellite images play a major role in setting up inventories of natural resources because they give a visual assessment of land use change over a period of time and provide quantitative information on the trade-off between different land use categories. Empirical evidence of land use change delivered by multi-dates aerial photographs and/or satellite images can greatly contribute to plan more appropriate management of the available resources, especially in developing countries, where other kinds of background data are often lacking. However, to come with fruitful recommendations, studies of

land use change have to be supplemented by investigation of their causes and effects.

Objectives

The main objective of the study is, to identify and determine over all trends of major land cover changes over a period of 23 years (1973-1996), using remote sensing techniques, and to relate them to physiographic and socio-economic processes, as well as to identify and analyze the factors behind these change as well as their impact on the environmental conditions.

Study area

The study area is located in the eastern part of the Sudan, east of the Gadaref state, between latitudes 15 and 13.15 North, and longitudes 35 and 36.30 East (Map 1). The drainage basin of the River Atbara has a total surface area of about 143.800 km² (37.7%) in the Sudan, while the study area lies in the southern part along the river Atbara Basin with a total area of 18.063 km² approximately, which represent 0.72% of the country's area. The area is characterized by high temperature throughout the year thus, the temperature is less important than rainfall in determining the climate of the area. April is the hottest month 42.9 °C while January is the coldest, 14 °C (Abu-sin 1970). Generally, the study area is sloping gently from southeast to the northwest; the altitude in the southern part reaches 1000 meters above sea level (ASL), and decreases north wards.

Methodology

In order to achieve this study, many sources of information were used such as satellite images, maps, references, reports, personal interviews and laboratory work (soil analysis). Ground check (field work) was also utilized for comparing information on the satellite images with the existing features of land use on the ground (visual interpretation).

Satellite Image Preparation

The study concentrated on the use of computer-assisted interpretation of digitized and non-digitized satellite images of the study area. Three sets of satellite images were chosen to investigate the changes which occurred between 1973 and 1996. The images of the area in 1986

and 1996 were obtained from the National Forest Corporation, while the images of the area in 1973 were purchased from the Sudanese Survey Corporation. In order to predict the changes that occurred, seven land use categories were distinguished (Table 1). A colour was assigned for each category (maps, 2-3 and 4).

The non-digitized images (1973 and 1986) were georeferenced by selecting four reference points, with known coordinates from the digital image (1996). By using International land and Water Information System (ILWIS. 30), three maps of land use were produced for the study area in 1973-1986-1996. These maps were changed to raster maps (images) again and then cross maps (maps of change) were produced (Maps 5, 6, and 7) in addition to six tables showing the changes in the seven land use categories.

Soil Sample Preparation and Analysis

Soil auger samples were analyzed to determine the soil texture (Sand, Silt and Clay), using Bouyococ method (Hydrometer), while Dry combustion (Resistance furnace) was used to determine organic carbon using Walkely-Blach method. Then the organic matter is calculated by the formula:

$$\% \text{ Organic matter} = 0.35 + (1.80 \times \% \text{ Organic carbon})$$

Nitrogen and Phosphorus determined using Kjeldahl and Olsen Na Hco3 methods respectively.

Land use category	General Description
Forests	Area covered by trees, forming closed, or nearly closed canopies, predominant species are Acacia species.
Hariq cultivation	The areas where farmers use the fire to burn bushes, shrubs and grasses for cultivation.
Mechanized rain-fed Agriculture.	Area allotted to rain-fed crop production by using machines in the different stages such as tillage, seeding and harvesting.
Range lands	The areas, which include group of vegetation such as bushes, shrubs and grasses that grazed by animals.
Traditional agriculture	Area of small agricultural production using hand tools. (i.e without application of machine).

Table (1). The land use categories from which changes were detected for the periods 1973 to 1986 and 1986 to 1996.

The results

Land use Change

In order to detect land use changes, remote sensing and geographical information system (GIS) techniques were applied to analyze satellite images of the study area in different periods (1973, 1986 and 1996). From the analysis, three tables showing the existing land use in these periods were produced (tables 2,3 and 4), while tables (5 and 6) showing the change in the land use categories including land use gained, lost or existed in the same category. Table (7) shows the extent and percentage of land use conversion in different categories for the period (1973 – 1986) and (1986 – 1996). Land use maps of the study area in the three periods were also produced (Maps 2,3 and 4). These maps were changed to raster maps (images) again then, three cross maps (map of changes) were produced (Maps.5,6 and 7). Map (8) produced to detect the change in Khashm El-Girba reservoir. From the previous tables and figures, the changes in land use categories (table 1) could be determined as follows:

Cultivated Area

Mechanized Rain-fed Agriculture (M.R.A)

In the year 1973, the portion of the mechanized rain-fed agriculture (MRA) was 276, 158 feddans, "about 5.5% of the study area", by the year 1986 this area expanded up to 500,039 feddans (about 10.02% of the total area). During this period (1973-1986), an area of 224.340 feddans (81.24%) of MRA were changed to other categories, while it gained about 448.115 feddans from them, and only 51,818 feddans (1.76%) remained in the same category (i.e. without change). Therefore the difference of land use in this category between 1973-1986 was +223,775 (81.33%) with an annual rate of +17,213 feddans (table 2).

In the duration between 1986-1996 the MRA lost about 149,011 feddans (29.80%) to the other categories, while it gained about 1,638,943 feddans from them with a difference of +1,489,932 feddans (29.80%) and annual rate of +148,993.2 feddans. Only 351,028 feddans (70.20%) remained without change. Forest and range lands were the main categories that gained considerable areas from MRA 58,419 ; 146,683 feddans respectively, between 1973 and 1986, while the rangeland was

the main category that gained from MRA between 1986-1996 about 140,776 feddans (28.15%). However, gaining from other categories, mainly forest and rangelands, about 159,863 and 56,835 feddans respectively between 1973-1986, and 175,514 ; 1,027,134 feddans respectively, between 1986-1996 compensated the losses of MRA area.

Traditional Agriculture

During the period between 1973-1986 the traditional agricultural area decreased from 356,568 feddans to 191,064 feddans only. The difference was - 166,034 with a land use change of 46.55% and annual rate of 12,771 feddans. This category lost 279,263 feddans to the other categories, while it gained about 113,229 feddans from them; about 77,395 feddans remained in the same category without change. Rangeland and MRA was the main categories that gained considerable areas from the traditional agriculture, 55.70% and 15.94% respectively. The change in the traditional cultivation between 1986-1996 was positive because it increased from 191,064 feddans to 289,860 feddans with a difference of +98,796 feddans (51.70%), and the annual increasing rate of + 9,880. MRA and rangelands remaining the main categories that gained wide areas from traditional agriculture 59,048 ; 22,052 feddans respectively. Within this period this category lost 82,988 feddans to the other categories while it gained 289,931 feddans from them, mainly from rangeland and forests, while only 108,076 feddans remained in the same category (i.e. Without change).

Hariq Cultivation

The area covered by Hariq cultivation shrank widely from 126,538 feddans to 70,67 feddans by 1986, during this period (1973-1986), 117,598 feddans transferred to the other categories, while 56,698 feddans gained from them and only 8,940 feddans remained without change, therefore, this category had a negative change (-60,900 fed.) with the annual rate of -4,684 feddans.

Hariq cultivation continued in its negative trend of change in the period between 1986 and 1996, it decreased from 70,670 to 44,568 feddans with a difference of -26,102 feddans and annual rate of -3,694 feddans, within this period, this category lost 60,682 feddans to the other categories, mainly rangelands, while it gained 39,572 feddans from them,

only 4,988 feddans of the Hariq cultivation remained in the same category without any change. Nature of the Hariq cultivation and its periodical loss placed the Hariq cultivation as a category of the higher change. Between 1973-1986 the change percentage was 92.93%, and it became 92.94%, between, 1986-1996.

Forests

Due to the vegetation clearance for agricultural expansion, the area covered by the forests diminished considerably between 1973-1986 from 957,747 feddans to 459,329 Feddans with a percentage change of 52.04 and annual decreasing rate of -38.34, fed/year.

Rangeland and MRA were the main categories that gained a considerable area from the forestlands 61.49% and 16.69% respectively of the total lost (804,496 feddans). The forests gained 306,062 feddans from other categories, mainly rangeland, this increase in area occurred in reserved forest (forests which under the protection of the National Forestry Corporation) mainly Rawashda, Wad-Kabo and Shashina forests. Only 153,251 feddans of the forestland remained within the same category (unchanged).

Between 1986-1996 the forest areas continued in the diminishing trend, it decreased from 459,329 feddans to 380,659 feddans with a change of 17.13% and annual rate of decrease -7.867 fed/year. Within this period forests lost 271,327 feddans to the other categories, mainly MRA and rangeland 38.21% and 18.86% respectively. While it gained 125,027 feddans from others, mainly land range (Table 3). Only 188,002 feddans of the forest stayed without change.

Rangelands

Considerable change was observed among the rangelands, it increased from 2,913,765 feddans in the year 1973 to 3,412,144 feddans by the year 1986, this was mainly due to the clearance of vegetation for the expanding agricultural area. The positive change within this period was +17.1% with annual rate of change +38,141 feddans.

The rangeland area lost about 546,162 feddans to the other categories mainly MRA, traditional agriculture and, forests 222,819, 68,986 ; 203,344 feddans respectively, while it gained 1,041,996 feddans from the other categories mainly MRA, traditional agriculture and forest 146,683 ;

198,653 ; 588,886 feddans respectively. About 2.367.603 feddans remained without change.

Between 1986-1996, according to the continuous expansion of MRA the rangelands changed to the diminishing trend, it decreased from 3,412,144 feddans to 2,270,002 feddans with a loss of 33.47% from its area by releasing 1,433,220 feddans to the other categories and gaining 291,761 feddans from them, about 1,978,924 feddans remained within the same category with a changing percentage of 42.00 and annual rate of change -14,630 feddans.

Discussion

Environmental Impact of Land use Change

In tropical regions the ecological balance is precarious. Soils, vegetation and forests need to be used with care and foresight if their fertility is to be maintained. The dry savanna is one of the most African's typical landscape. The hardy acacia trees provide animal fodder, timber, fire wood and shelter from the sun. People have gained living in some of these areas for centuries because they have been able to recognize and respects the limits of their local, natural environment. Misuse of natural resources has led to land degradation which are caused directly by three main types of land misuse: due to the increase of human and animal population. The main causes of the land misuse in the study area are over cultivation, over grazing, and deforestation.

None of these types should be thought of as the dominant cause of environmental degradation since they are all interrelated. The change in spatial distribution and intensity of one land use can affect directly other land uses. Moreover, land missus can be accelerated by drought, and is also greatly influenced by various sectors such as social, economical, and political factors.

Impact of cultivation

The main type of land use practice in the study area is rain-fed cultivation, particularly sorghum and sesame. This activity has a far more intense impact on the soil because it requires complete clearance of vegetation, cultivation of the soil, the growth of crops, and followed by grazing of the stubble that remains after harvest of crops. The soil is therefore, exposed to these practices each year for long periods.

Cropping can be sustained in sub-humid areas and the wetter parts of the semiarid areas (in the southern part of the study area). But where it spreads to drier parts of more marginal areas (northern part of the area) extensive soil erosion can result. To study the environmental impact in the study area, it is better to divide cultivation activity into, traditional cultivation, and mechanized rain-fed agriculture.

Traditional Cultivation

The cultivation of arid and semi-arid lands are limited by the fact that soils are usually poor in nutrients and organic matter due to the limited rainfall that has leached only small proportion of nutrients from the topsoil to the lower subsoil and resulted in a poor vegetation cover unlike wetter areas. There is also long hours of sun shine throughout the year to provide energy for the growth of plants and enhance evapotranspiration. Traditional system of rain-fed cropping was developed over thousands of years to make the best use of limited rainfall and to sustain food production even in the most adverse climatic conditions, (Granger, 1990). In this type of cultivation farmers sometimes use the fire for land clearance (hariq Cultivation), the ash, which is produced from the burning of the grass, bushes and small trees, improves the soil fertility.

In the traditional system, farmers aimed to reduce the risks of a complete crop failure by planting variety of crops. Because each crop has different water requirements, therefore a good chance that one of them would survive even if the rain was late or of limited quantity, This type of cultivation sometimes is characterized with shifting from place to another due to many reasons such as: nutrients shortage, loss of soil structure, weeds, parasites, pests and diseases. In this type of cultivation, farmers cultivate a land for a few years until the fertility of soil begins to decline. Before the land is completely exhausted, the farmers leave it fallow and move elsewhere to start again. If it is left long enough, the natural vegetation re-grows in the fallow area and restores it's fertility, the land is then ready to be cultivated again.

The rising demand for food to feed growing population forces farmer to increase production, either by reducing fallow periods, or by expanding cultivated area. The shorter fallow depletes soil nutrients and decrease organic matter because of insufficient time for the fertility to be

restored before the next crop is planted. The soil becomes more susceptible to erosion because of the lower organic matter content and the fact that the soil is left without vegetative cover for longer periods each year.

Mechanized Rain-fed Agriculture

Modern rain-fed agriculture using tractors, disc harrows and sometimes-mechanical harvesters are practised in the study area. Land is leased by the State for individual investors where by each individual is allocated 'a farm', its extent ranges from 1000 to 1500 feddans These schemes are managed by both private and government sectors. Sometimes rotation of *Dura*, sesame and fallow with or without cotton are practiced, but often a piece of land is cropped with *Dura* until the land loses its fertility and then abandoned completely. Since the introduction of mechanization in the area more emphasis was given to horizontal expansion rather than to increase production vertical. In the years from 1950 to 1952 the total area under mechanized rain-fed farming in the study area was 11,375 feddans, at present the cultivated area exceeds a million feddans, half of which is unauthorized by the M.F.P.C (Mechanized Farming Public Corporation), So there is a spread without any control by concerned technical authorities or land use department. The development of mechanized farming in the area and its spread without control or appropriate environmental measures led to negative environmental impact as a serious decrease in the grazing resources and forests (as shown in table 6) and as well, decrease soil fertility.

Impact on Rangeland

The expansion of mechanized rain-fed agriculture in the area did not take into consideration the animal resources, which were gradually bushed out of the traditional potential grazing lands. Thus, with increasing livestock numbers led to high pressure on the grazing lands, over stocking and, consequently over gazing. The overstocking rate in the area in 1983 was 8.36 % (El-Tom, 1975), which have more bearing on the environmental degradation in the area. Extensive areas of the range lands have been overgrazed to a point that now became bare land (El Hessian, 1981). He also pointed that there was a decrease in silt and clay content of the overgrazed area witch indicate the occurrence of erosion.

The expansion of mechanized farms into former grazing lands blocked traditional stock routes and contributed to the conflicts between the nomads and farmers. Police centres reported that there are continuous increase in conflict cases between the farmers and nomads. In 2001, there was 924 cases in the southern part of the study area (Galabat), 952 in the middle of the area (Alfashaga), and 543 cases in the northern area (Khashm El-Girba).

Impact on Soil

Traditional rain-fed agriculture system often includes extended fallow periods during which vegetation can regenerate and soil fertility can be replenished. But the clearance of vegetation cover to facilitate the usage of machines in the different agricultural stages expose the top soil to erosion by wind or water (plate 1) resulting in soil degradation.

Depletion of Soil Fertility

Soils in the Sudan are generally poor in many mineral contents and its fertility has seriously and rapidly been depleted in the continuously cultivated lands. Fertility depletion is more evident in areas under rain-fed cultivation especially in Gadaref area. Fertility depletion in the study area is so high that average yields are estimated to have dropped over 50% (Abdel-Ati, 2002), Absence of crop rotation, rarely application of fertilizers, and disappearance of fallow periods are the main reasons behind that.

The percentage of the organic matter in the study area varies due to the variation in the land use category. In the agricultural area higher percentage is found to be in the topsoil (2.11%) and it decreases with soil depth. The higher percentage of organic matter in the forest soil (2.11%) has been found in the soil depth (30-60 cm), while in the pasture it is about (2.15%). Accordingly, the organic matter in the area is low in the different land use categories. This is may be due to fast decomposition and the erosion activity, which washes the organic matter especially in the agricultural areas.

Nitrogen is one of the various plant nutrients. Nitrogen probably has been subjected to extensive studies and even yet is receiving much attention. The amount of nitrogen in the soil is small, while the quantity absorbed annually by crops is large. The soil nitrogen is readily soluble

and usually lost by drainage. It could be stated that, the soil in the study area is low in nitrogen content in all land use categories (i.e. agriculture. Forest, pasture). The small amount of nitrogen is concentrated in the topsoil (depth of upper 10 - 30 cm). The low content of nitrogen in the agricultural soil is mainly due to the absence of the leguminous plants in the rotation, which fix the atmospheric nitrogen into the soil so as to be available for absorption by plant.

With the possible exception of nitrogen, no other element has been as critical in the growth of plant in the field as the phosphorus. The lack of this element is serious. Importance of the phosphorus could be seen through the enhancement of root development, flowering, fruiting, crop maturation, quality and resistance to certain diseases.

The soil chemical analysis revealed that the available phosphorus is generally low and it tends to decrease with soil depth. The top soil of the forest area has (4.2 p.p.m.), and with less content in the subsoil of the rangelands. According to the deficiency of phosphorus in the soil, coupled with the absence of fertilizer application, thus the advantages of the phosphorus are lacking.

Soil Compaction

Unappropriate cropping using heavy machinery leads to soil compaction, in the form of either surface crusting, or the subsoil compaction under the weight of tractors and other heavy machinery. Tillage, seeding and harvesting are the main operations that caused the soil compaction in the study area. Tillage-induced compaction that caused by primary tillage under more than optimum soil moisture conditions and by excessive secondary tillage. This tillage destroys soil aggregation and stimulates the surface soil to puddle, crusting and increases bulk densities higher than an untilled area.

Soil compaction which caused by agricultural machinery occurs at the top soil between 15-30cm. Compaction affects the water balance in the soil by increasing runoff because less water can penetrate the compacted zone. When runoff increases soil erosion starts and some gullies appear (plates 2, 3, 4). Soil compaction enhances plant-water stress, nutrient deficiencies, shallow root system, and reduction of the yield. The water surface run off removes nutrients and clay particles

therefore, the percentage of the sand on topsoil is slightly high. Accordingly, the soil productivity decreases.

Impact on Soil Texture

Texture of the soil is usually determined by the size and distribution of the soil particles (sand, silt and clay). The physical data reveal that, there is a reduction in the clay content and increase of sand particles in the top soil and decrease with soil depths. It is obvious that, soils become degraded when sand particles increase on the top of it, because of removal of fine particles by erosion agents (wind or water). The introduction of mechanized rain-fed agriculture led to soil compaction and consequently increased the water runoff that enhanced soil erosion processes which removed fine particle (clay and, or organic matter) from the topsoil. Fine particles in soil especially the clay is an important factor in moisture availability in arid and semi-arid areas (Northern area of the basin) because the soil capacity to hold moisture increases with the higher content of silt and clay (Brady, 1974).

Impact of grazing

The northern part of the study area (South-east of the Butana area) with its limited amount of annual rainfall (less than 300 mm) is only suitable for grazing. Traditionally, this area is known as one of the best grazing lands in Sudan, due to the occurrence of *Belpharis sp.* (Siha) and other palatable grasses. It was reported that *Belpharis* had disappeared from the area (Harrison and Jackson, 1958). This good grazing land has become the target of the mechanized rain-fed agriculture, which started at *Gadambaliya* area and spreaded rapidly to the rest of the area, as a result, more grazing land has been taken to be under cropping. This change in land use subjected the area to a great stress. The investigation of land use change, showed that, the study area suffered from overgrazing through the followings:

Expansion of agricultural areas

The available area for grazing has decreased as nomads had been displaced by farmers growing crops either on marginal rangelands previously used for grazing, or on former dry season pasture, mixed within agricultural zone. The rangeland area determines the density of grazing animals and the propensity for overgrazing. Livestock density

may rise when this area is reduced by the encroachment of other types of land uses, especially mechanized rain-fed agriculture which expanded from 276,158 feddan in 1973 to 500 039 feddans by 1986 and it reached 1,654,740 feddans in 1996, on the other hand the range lands had a little increase in area from 2,913,765 feddans to 3,412, 144 feddans between 1973-1986 due to the removal of vegetation from the forest lands The rangeland area decreased from 3,410,144 to 2,270,002 feddans (between 1986-1996) due to the expansion of mechanized rain-fed agriculture.

Deforestation also caused a decline in the fodder quantities of rangelands. Although we might think of shrinking rangelands merely in term of a reduction in the area of grasses available for grazing, as far as livestock are concentrated in rangelands, there are three dimensional assemblies of fodder, in which grasses, shrubs and small trees are all valuable fodders. Yet in the area fuel wood shortage and the illegal production of charcoal are the main reason behind the slowness of vegetation recover (plate 5) this together with the less extreme hacking of branches, destroy a vital source of fodders for livestock. Deforestation also reduces the soil protective cover and rendering it more prone to erosion by both wind and water.

Increase of livestock numbers

The most common cause of overgrazing is simply the increase in the number of the grazing animals. All the animal categories (camels, sheep's, goats, and cattle) have increased in the period between 1994-2000. The animals increased during this period from 1.473.236 to 1.896.128 animals unit. Concentration of animals around the water points (Hafir) also put the area under grazing stress and resulted in soil and vegetation degradation around these points.

Livestock raising in the area is predominantly nomadic. Pastoral tribes follow specific transhumance routes in their seasonal movements, which are dictated mainly by the need for, forage and water. During the dry season they stay in their grazing lands in the southern part of the area and near water sources (River Atbara and it's tributaries). With the onset of the rainy season they start to move northwards to avoid the biting insects and the inconvenience of the sticky muddy soil. Animal concentration thus occur at the movement routes on the higher lands which is shallow soil mainly on rock out-crops and this led to land

degradation through soil compaction and sealing resulted from the trampling of livestock in the animal routes (plate 6), and thus expose the soil to erosion by wind or water.

Change of Vegetation Species

Degradation of the grazing vegetation in the area takes two main forms. The first involves a reduction in the overall density of vegetation cover and the proportion of land covered by vegetation. This reduction takes place when trees are cleared for cropping, grazing and, cut down for fuel wood or fodder or over browsed by camels. The second form of degradation involves a change to less productive type of vegetation cover, involving a modification in species. On overgrazed rangelands have less palatable annual grasses and thorny stunted shrubs, both of which are characteristic of the less productive ecosystem of drier climate.

In the study area some of the most palatable and nutritive plants have disappeared to be replaced by undesirable species that are either less palatable or totally unpalatable. Siha *Blepharies spp.* once dominated the northern part of the area but has been replaced by "Nal" *Cymbopogon nervatus*, and "Gao" *Aristida spp.* "Bogheil" *Blepharis spp.* Was formerly common in the area but now is found only in a few isolated areas (Khogali, 1986). Other plants are more ephemeral, springing up with the onset of the rain rather than having a permanent presence, and they decrease the durability of rangelands.

Overgrazing affects the vegetation cover, the soil and even the health of the animals themselves. The erosive process related to grazing are not an inevitable consequence of the development of herding, even though they seem to be highly related to grazing density. It is known that intensive grazing can diminish significantly the protective vegetation cover, reduce infiltration rate and increase surface runoff (Berry, 1962). These in turn increase erosive processes and the production of sediments. However, it has been proved that controlled grazing can be compatible with the conservation of natural resources (El-Hassan, 1981).

Deforestation

The current annual rate of forest depletion in the Sudan is 1.6%, this means, if this rate continued, Sudan's lands will lose all its forests in no more than 21 years (Abdel Ati,2002). According to El-Siddig, (2001) the

forest cover has declined from 40% to almost 10-12% of Sudan total area as estimated by the National Forest Inventory of 1996. The vegetation cover in the study area increases as we move southward, due to the increase of rainfall, the open woodland that still cover large areas in the south consist of trees and shrubs of modest heights that are widely scattered across the area, named (open woodlands), in contrast to close forest like the tropical rain forest. The forest canopy is more open and cover a lower portion of the ground surface. Open woodland may look less impressive than the dense forests of the humid tropics, but they have a very important role in the local economy as source of building materials, fuel wood and fodder. The forests in the study area could be divided into reserved and non-reserved. The main policy is to concentrate filling and regeneration of trees inside the reserves forest and to be managed in a way that guarantees its development. Rwashda and Wad Kabu are good examples for the reserved forests in the area. According to the study, Expansion of agricultural area, Fuel-wood production, as well as char-cool production is the main causes of deforestation in the area (Plates 5, 7, 10, 11 and 12).

Conclusion

The upper basin of the River Atbara is one of the richest part of the Sudan in natural resources. For the users and decision makers these natural resources are regarded as non-exhaustive, this research is based on the consequences of the false concepts which led to adverse effects on natural resources of the area. Misuse of natural resources is a direct cause of land degradation in the study area due to the land use changes specially the expansion of mechanized agricultural areas on the account of range lands (Marginal lands).

Rain-fed cropping is the dominant form of crop production in the study area, and it accounts for the total cereal production. It is unlikely, that this situation will change very much in the medium term, so urgent actions are needed to increase the productivity and sustainability of rain-fed cropping, both to meet food production targets and to bring land degradation under control.

Various techniques were invented and developed during the last decades to monitor land use and resources management. They range from the simple field survey carried out by small groups of surveyors to

the most complex operations of remote sensing monitoring carried out to a large extent by electronic equipment in satellites and receiving stations. Each technique has its special advantages and disadvantages. Not one technique, but a combination of several techniques must be applied to achieve the land monitoring which is definite in its classification, complete in its coverage, up to date with its information and repetitive in its compilation. Monitoring land degradation in semi-arid environment is encountered by many problems concerning data availability and appropriate methodological approaches. Remote sensing and G.I.S. as a recent integrated techniques for data capture and analysis have been considered in this study to investigate and assess land degradation as a result of land use change in the upper basin of the River Atbara and proved to be powerful tools.

Recommendations

The direct cause of environmental degradation presented in the study is the improper land use. If land degradation is to be controlled and the productivity as well as conservation of the natural resources are to be sustained the following recommendations should be considered:

1. To achieve the goal of sustainable agricultural development, priority must be given to maintaining and improving the capacity of agricultural land with high potential to enable it to support the expanding population. However, conserving and rehabilitating lands and other natural resources with lower potential in order to maintain sustainable man/land ratio is also necessary.
2. Increased crop production will have to come from more intensive use of the better farming lands rather than expanding the area under cultivation through application of improved drought-resistant varieties (IDRV) and increasing the use of fertilizer.
3. The addition of organic matter and deep tillage will increase soil fertility and crop productivity and lessen erosion.
4. Traditional cropping systems, such as four-year rotation and sequence of fallow are suitable to maintain soil fertility where livestock would be able to feed on crop residues, so as to deposit their waste on the fields.
5. Introduction of suitable water-harvesting techniques to increase productivity and concern the environment.

6. In sloping areas the cropping practices (tillage) should be against the contours by terracing to increase moisture and lessens water erosion..
7. Encouragement of Trees planting on water sheds is vital to protect the land from soil erosion, provide wood fuel and fodder.
8. Improving the quality of livestock by controlling diseases and selective breeding to increase the average yield per animal, and avoid over-grazing. To encourage nomads to herd more camels and fewer cattle may be in the interest of both the pastorals and the environment.
9. Improving rangelands by reseeding palatable grasses, allowing time for re-generation and planting forage crops.
10. It is vital to alert public awareness to the need for immediate action before the situation becomes even more worse.
11. Establishment of reserve forests must be encouraged in the middle and south of the area.
12. Forest Society, in which local people plant trees outside regular forest area, seems to be the only viable long-term strategy to meet a forestation targets. Re-forestation by refugees in the area should be encouraged.
13. States governments must provide farmers and cattle owners with technical assistance and extension services, access to credit, improved marketing facilities, price support, and help in the formation of co-operative organization.
14. Semi-arid environment need to be investigated through the system analysis techniques for development of a soil information as well as other natural resources information systems. land use planning researches based on environmental impact analysis and assessment of the land resources is a must.

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