Land Cover Changes and Their Driving Forces at Sharq Alneel Locality, Khartoum State: Testing Remote Sensing Data

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Abstract

The extension of bare lands at the expense of productive lands has been a repeated phenomenon in different places on the earth's surface and there are many evidences which indicate human misuse of land that accelerating this phenomenon. The main objective of this paper is to detect land cover changes at Sharq Alneel Locality, Khartoum State in 20 years (1995 - 2015), and to show their driving forces. The paper used remote sensing technique, which considered as one of the most important recent means that facilitates efficient decision making for resources management, as baseline tool to detect land cover changes. This technique has been supported by qualitative interviews. Tow satellite imageries were used in this paper: Thematic Mapper (land sat 5, TM 1995) and Operation Land Image (land sat 8, OLI 2015) which are digitally processed using ERDAS Imagine 2014 to classify land cover types of the study area. The images were classified into four classes: natural vegetation, bare lands, agricultural areas and residential areas using supervised classification method and then post-classification technique was applied to identify the changes in the years (1995-2015).The analysis of the satellite imageries showed the transformation of natural vegetation cover to bare lands. The findings showed that natural vegetation cover decreased from 5156 km^2 in 1995 to 2710 km^2 in 2015, while bare lands increased from 2744 km^2 in 1995 to 4454 km^2 in 2015. All other types of land cover of the study area were increased at the expense of natural vegetation cover. These changes indicate to the acceleration of land degradation as a normal consequence of human misuse of land and absence of ongoing monitoring and assessments of these natural resources by the specialized authorities.

Keywords: land cover, remote sensing, change detection, driving forces, Sharq Alneel Locality

Introduction

Humans have been altering land cover since pre – history through the use of fire to flush out game and, since the advent of plant and animal domestication, through the clearance of patches of land for agriculture and grazing, therefore, the physical surface of the earth is in constant change: abundant water resources give rise to new growth, cities expand, what was once forest is converted to form bare land. Man causes some of these transformations others are merely the result of the changing seasons (Steffen, et al., 2003). Land use and land cover dynamics are widespread, accelerating, and significant process driven by human actions but also producing changes that impact humans (Rajan and Shipasaki, 2001, Yongnlan et. al., 2003, Franck and Yanni, 2006). These dynamics alter the availability of different biophysical resources including soil, vegetation, water, animal feed. Consequently, land use and land cover changes could lead to decreased availability of different products and services for humans, livestock, agricultural production and damage to the environment (Oumer, 2009).

Problem and Justification

At present, natural resources in Sudan in general face severe and alarming degradation compared to what is used to be decades ago (Karrar, 2010). In Sharq Alneel Locality the prevailing range lands are poor; grasses disappear after one or two months after the rainy season. Pastoralists harvest the natural grass to feed their animal in the severe periods. Agricultural and settlement expansion have encroached on wooded areas, growth of animal population, particularly goats has put even more pressure on the natural vegetation through overgrazing creating the typical desert perimeter around settlements and first of all the prevailing semi – arid climate in the study area, so Sharq Alneel Locality has been subjected to dramatic changes in land cover and accordingly, gathering information about Land cover changes is fundamental for a better understanding the relationships and interactions between humans and the natural environment.

Objectives

The objectives of this paper is to detect land cover dynamics over a period of 20 years testing the accuracy of remote sensing technique in characterizing and detecting land cover changes as well as to identify the drivers which have caused these land cover changes.

Conceptual Framework

The renewable natural resources of many African countries – among them Sudan – have come under severe strain over the past two or three decades and most indicators point toward a continuation of this trend (Adam et. al., 2014, Ayoub, 1998). The rate of degradation and depletion of these resources has been accelerated in proportion to the increasing population pressure: overgrazing, deforestation, desertification, soil erosion and salinity have degraded the environment so that the food security and economic development of many countries are threatened (Antonio, Louisa, 2000).

Accurate information of land cover changes and the forces and processes behind is essential for designing sound environmental planning and management. Land cover analysis provides the baseline data required for proper understanding of how land was used in the past and what types of changes are to be expected in the future. Studies of land cover changes also yield a valuable information analysis to the resource manager because it provides information that would help in resolving conflicts between human use of natural resources and the function of natural systems (Tegene, 2002, Silva, 2010).

Empirical studies by researchers from diverse disciplines found that changes in land use/land cover has become key to many diverse applications such as agriculture, environment, ecology, forestry, geology and hydrology (Weng 2001). These applications referred to crop land loss, soil degradation, urban expansion, water quality change etc. At the same time, according to (Lambin, 1997) in the past decades, a major project to study land cover change has emerged as an international initiative and has gained great impetus in its efforts to understand forces driving land cover change. These efforts have stimulated the interest of researchers to apply various techniques to detect land cover dynamics at different levels. Change detection has emerged as a significant process in managing and monitoring natural resources and urban development and there are a lot of available techniques, among them post-classification comparison, that serve purpose of detecting and recording differences and might also be attributable to change (Singh 1989; Yuan et al. 1999). Though, simple change detection is seldom adequate in itself: there is a requirement of information regarding initial and final land cover types, the ‘‘from-to’’ analysis (Giri et al. 2005). Remote sensing data and GIS are the most common methods for quantification; mapping and detection of patterns of land cover changes because of their accurate geo-referencing procedures, digital format suitable for computer processing and repetitive data acquisition (Lu et al. 2004; Chen et al. 2005; Nunez et al. 2008). In particular, by means of the integration of remote sensing and geographic information system techniques, it is possible to analyze and to classify the changing pattern of land cover during a long time period and, as a result, to understand the changes within the area of interest (Haack 1994; Chan et al. 2001).

Literature Review

The detection of possible differences that may occur over time is a key factor when analyzing the state of an area. These differences may be caused by several phenomena that include human activity and natural causes, as described in (Singh 1989; Yongnlan et al. 2003; Serra et al. 2008; Nori et al. 2008; Parakasam 2010; Njike 2011). Many studies were focused on the causative factors of land degradation in Sudan using remote sensing technique; (Ayoub 1998; Al Awad 2000; Nasr 2004; Abdelmagid 2008; Al-Khaleifa 2010; Fashir et al. 2012; Adam 2014; Abdelrahim & Abdalla 2015; Sulieman 2015) stated that overgrazing and over cultivation especially rainfed agriculture were the most widespread causes of land degradation. Case studies based on remote sensing indicate that forest cover in the Sudan is declining at varying rates. (Khairy 2003 and Albaghir 2010). Elsiddig 1999 reported that forests are converted to mechanized farms at approximate 0.5 million hectares per annum. This estimate is very close to Forest Resource Assessment (2005) estimate of annual rate of forest clearance in the Savanna zone of 0.54 million hectares per annum and then deforestation is one of the causes that degraded the lands. The study area has received little attention even though land degradation is widespread phenomenon there (Halwagy 1961; Amna et al 2013; Hilmi and Sedahmad 2014; Horn 2014), reported that the residential areas expanded at the expense of natural vegetation and many new extensions were planned in flood regimes.

Methodology

Study Area

Sharq Alneel Locality, ($15^o15^`$–$16^o13^`$N, $32^o37^`$– $34^o23^`$E) located at dry land semi – arid regions in central Sudan east of the River Nile within Khartoum State covering an area of about 9,540 Km^2 which is equivalent to more than one–third the area of Khartoum State and where the annual rain fall is not exceeding 200 mm and with a population of about 1000000 according to the estimation of population census in 2014. Ecologically the study area is classified as semi – desert Acacia *tortilis* – *Maerua* Crassifolia desert scrub and semi desert grass land on clay and sand according to Harrison and Jackson (1958). It has a flat nature and gently sloping ground surface, most of which is covered with poor rangelands and vast areas of sand sheets, (figure 1).

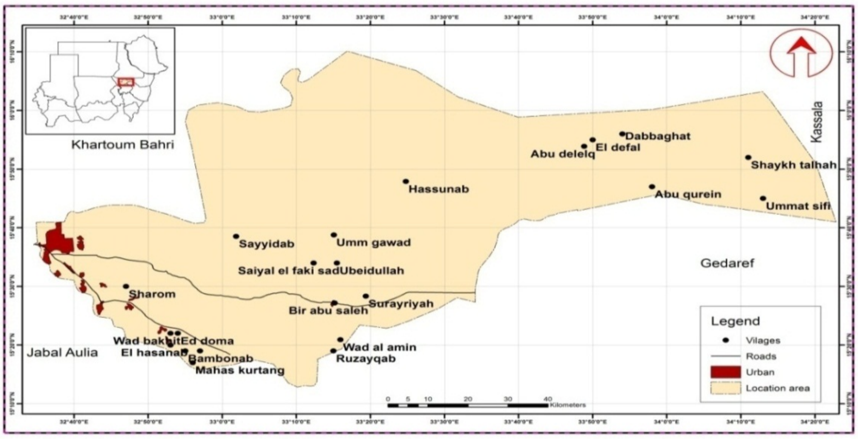

Figure 1
Sharq Alneel Locality

Data and Processing

The processing in this paper was divided into two steps; gathering and analyzing remote sensing data, and field work (figure 2). Data in the form of satellite imageries were analyzed qualitatively (visual interpretation) and quantitatively (information is extracted by the aid of computer).Two multispectral satellite imageries of the study area were acquired for two dates 1995 and 2015 and their specifications are given in table (1).

Table 1
Satellite Data Specifications

Instrument	TM	LOI
Satellite	Land sat 5	Land sat 8
Date	February 1995	February 2015
Path/row No	173/49	173/49
Orbit and coverage	705 km and 16 days	311 km and 8 days
Resolution (meters)	30 by 30	30 by 30
Dynamic range (bits)	8	12

Due to acquisition system and platform movements, remotely-sensed data from aircrafts or satellites are generally geometrically distorted. The two images were geometrically corrected using geo-referencing so-called ground control point with known co-ordinates to the corresponding pixels in the images. The data base was providing by the topographic sheet scale of 1:250000. The original TM bands 3, 4 and 5 were selected as classification bands and supervised classification was executed using maximum likelihood classification algorithm, so the two satellite imageries were studied by assigning per-pixel signatures and differentiating the land area into four classes, (natural vegetation, bare lands, agricultural areas and residential areas), on the bases of the specific Digital Number value of different landscape elements. Each class was given unique identity and assigned a particular colour to make them separate from each other. Because the supervised maximum likelihood classification is based solely on spectral properties, the accuracy of classification results was not sufficient to meet our needs in detecting temporal variations in land cover. A post classification change detection technique performed in ArcGIS 2014 was used to improve accuracy. To ensure acceptance based on accuracy, we took sample points from the classified images in 1995 and 2015. Subsequently, direct comparison of land cover types was carried out on the basis of geographical location, with available primary data such as land use maps in 1995 and 2015. We then used a Kappa coefficient to evaluate accuracy. The Kappa coefficient was 90.1% for 1995 and 95 % for 2015, ensuring our confidence in the accuracy of the classification.

The data from field survey was in the form of qualitative interviews with individuals, pastoralists and farmers believed to have a good knowledge and information about the history of the study area. Semi structured interview technique was used because it is a controlled and well prepared method since it is based on an interview guide as described by Berge (1998). Questions concerned the changes in land use and natural vegetation cover, their causes, changes in climate factors, trend of land degradation and other institutional issues.

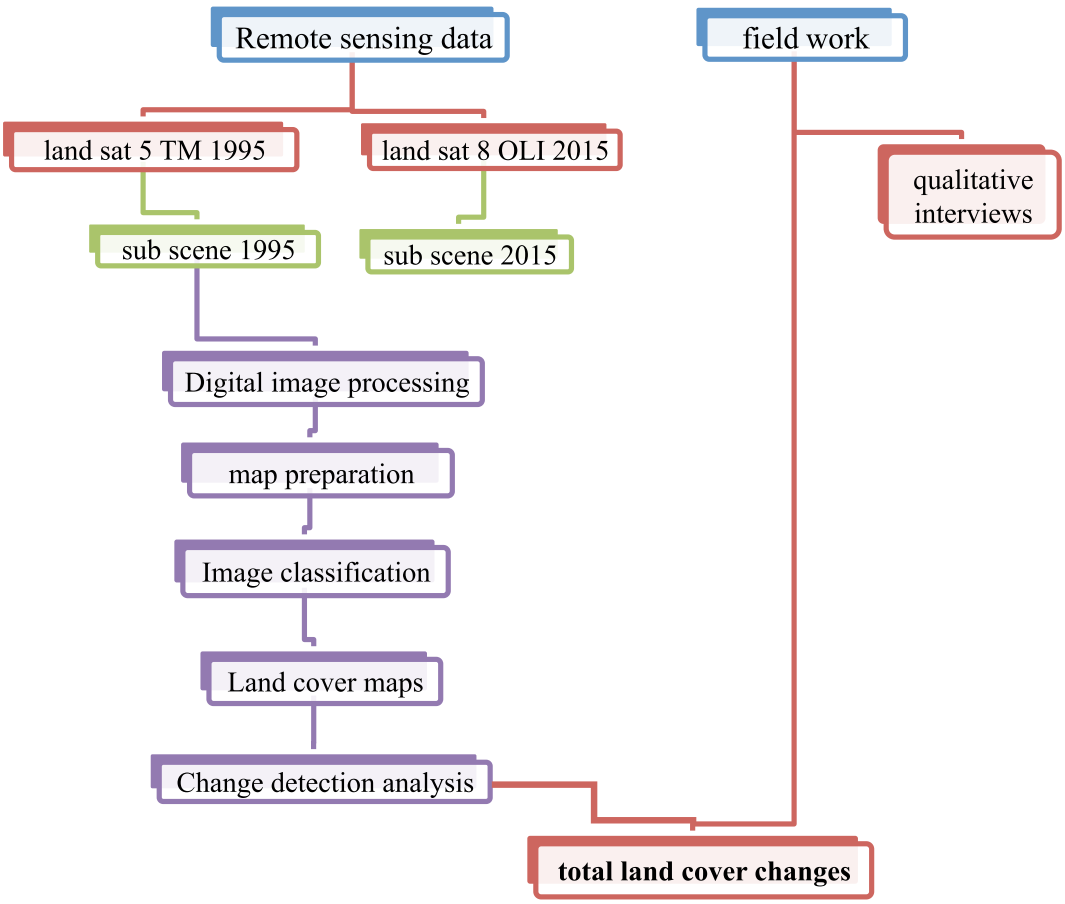

Figure2
Flowchart of data analysis

Results

The classification results show that there is a high rate of changes of all land cover types of the study area. (Figure 3) and (table 2) found that the natural vegetation cover lost about 47% of its area in 1995. It decreased by 2446 km^2 from 5156 km^2 in 1995 to 2710 km^2 in 2015 representing only 28.4% of the total area. In so doing, agricultural area expanded largely in different areas. It increased at the expense of natural vegetation cover from 1592 km^2 in 1995 to 2206 km^2 in 2015 representing 23.12% of the total area. Bare land expanded in huge area, it increased from 2744 km^2 in 1995 to 4454 km^2 in 2015 representing 46.69% of the total area and rate of change about 62% of its area in 1995. Also bare land increased at the expense of natural vegetation cover. There is a great change of residential area, it increased by 122 km^2 from 48 km^2 in 1995 to 170 km^2 in 2015 representing 1.78% of the total area and rate of change about 354% of its area in 1995.

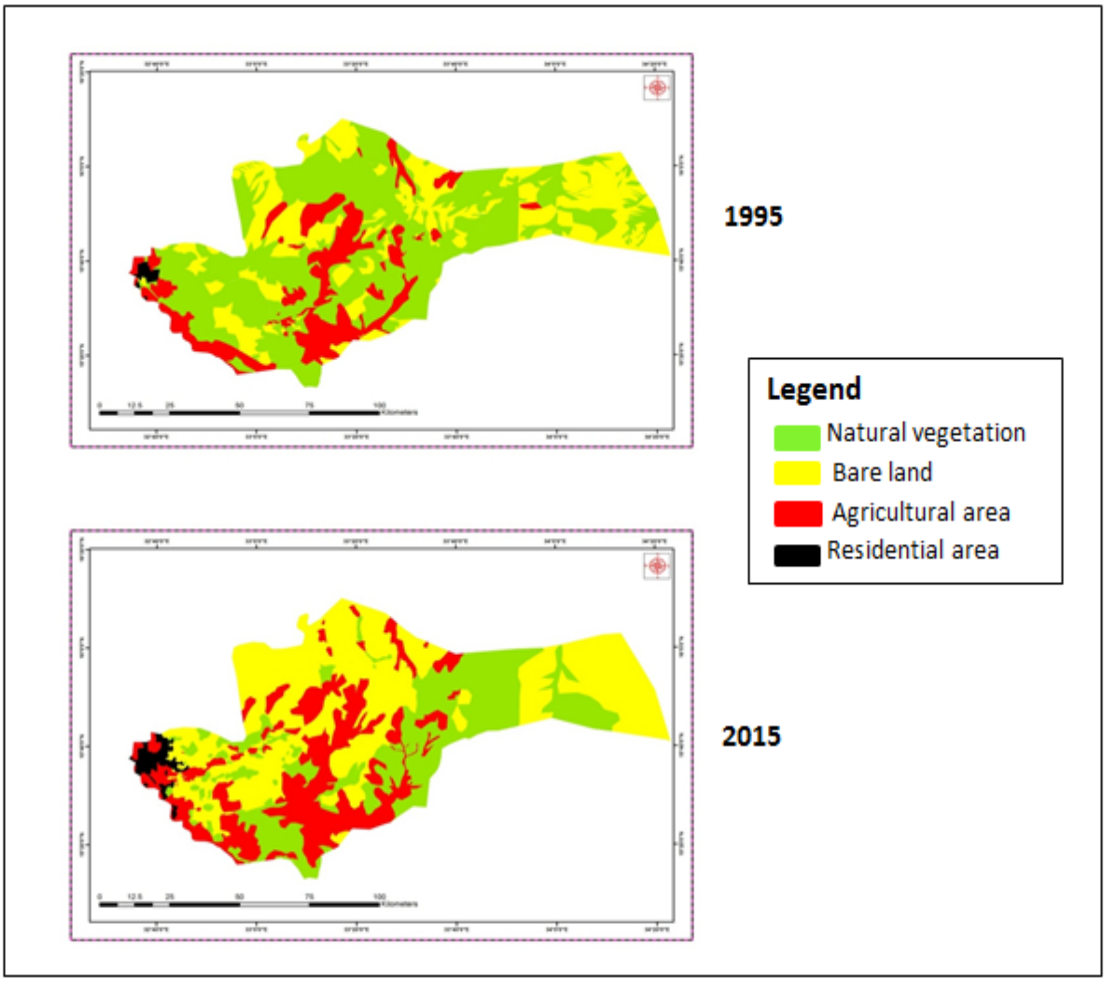

Figure 3
Land-cover patterns in the study area, 1995 and 2015. (Based on RS data)

Table 2:
Land Cover Changes of the Study Area from 1995 to 2015

No	Land cover type	Area in 1995 km^2	Area %	Area in 2015 km^2	Area %	Difference in km^2	Rate of change %
1	Natural vegetation	5156	54.05	2710	28.4	-2446	-47.4
2	Bare land	2744	28.76	4454	46.69	+1710	62
3	Agriculture	1592	16.69	2206	23.12	+614	38
4	Residential area	48	0.50	170	1.78	+122	354
Total area		9540	100	9540	100		

Information from the field work revealed that the most land cover decreased in the study area, according to the interviewee, is the natural vegetation, and the most land cover increased is bare land followed by agricultural areas and residential area. In spite of the fact that the residential area is increased by the rate of 354% of its area in 1995, it is remained occupying very small area when it is compared to the whole area (figure 4).

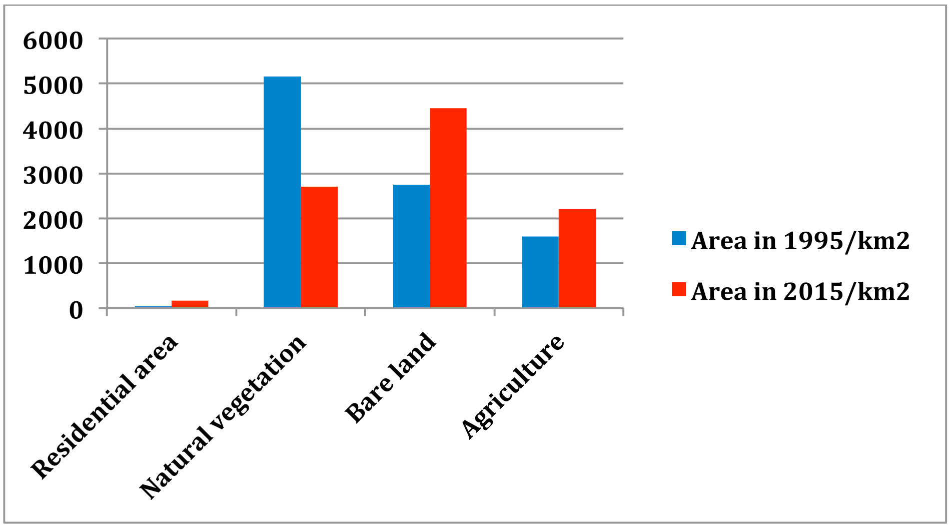

Figure 4: Changes of Land Cover of the Study Area (1995-2015)

The most obvious statement, Sharq Alneel Locality has experienced a considerable change in all types of land cover. To sum up, the natural vegetation cover is the most land cover of the study area that decreased significantly, it lost nearly half of its area in 1995 (47%) and bare land constituted as the most land cover that increased significantly (62%). Bare land, agricultural area, residential area were increased by 33.1%, 11.9%, 2.4% respectively at the expense of natural vegetation cover (table 3). This continuing decrease of natural vegetation with high rate expansion of bare land is strong indicator to land degradation of the study area.

Table 3

Major Land Cover Conversions from 1995 to 2015

From Class	To Class	1995-2015 area km^2	Rate of conversion%
	Bare land	1710	33.1
Natural vegetation	Agricultural area	614	11.9
	Residential area	122	2.4
Total loss of natural vegetation cover		2446 out of 5156	47.4

Discussion

Driving Forces

The study area is completely located at semi – arid eco – climatic zone with very harsh conditions and diversity needs for human activities. No doubt, under such conditions man plays the most powerful and persistent role causing or contributing to such land cover changes. During the last decades, the study area has been subjected to successive drought which influences negatively the natural vegetation cover. Accordingly, it commonly emphasized that while drought causes a quantitative decrease in natural vegetation cover, man forces intensify using the environment and resources and thus contributing positively to land degradation.

Climate Factors

The study area is sparsely vegetated as a result of the low amount of rainfall. The vegetation is exposed to extreme conditions and must survive drought, which can stretch over several years with little rainfall. In semi-arid ecosystems with a single rainy season there is usually a short growth period followed by a long dry season with a great reduction in the amount of green plant material (Sulieman, 2015). Rainfall is the most important climatic factor in the study area. Most of people and their livestock depend on the amount of rainfall that falls to support the growth of the plants. In the years of heavy rainfall rich growth of green vegetation will be simulated, while in poor conditions of rainfall grass-failure occurs.

The inconsistency and unreliability in rainfalls are prominent characteristics of the arid climate of the study area. (Table 4) and (figure 5) show the fluctuation of rainfall amount which entails fluctuation of vegetation growth. According to rainfall variability, it is useful to consider the possible changes in the aridity conditions. Generally, there is an increasing trend of temperature as reported by Elagib and Mansel 2000 that the mean annual temperature in Sudan have increased significantly by 0.076° C – 0.2° C per decade specifically in the central Sudan where the study area is located. The temperature, especially during the dry seasons affects rainfall availability. To sum up, for such climatic changes in rain fall and temperature the acceleration in bare lands encroachment will be expected.

Table 4

Rainfall Variability of Khartoum State

year	1970	1980	1990	1995	2000	2005	2010	2015
Rainfall/mm	77.2	74.7	44.8	195	60	140.7	76.5	166.4

Source: Meteorological authority, Khartoum 2015

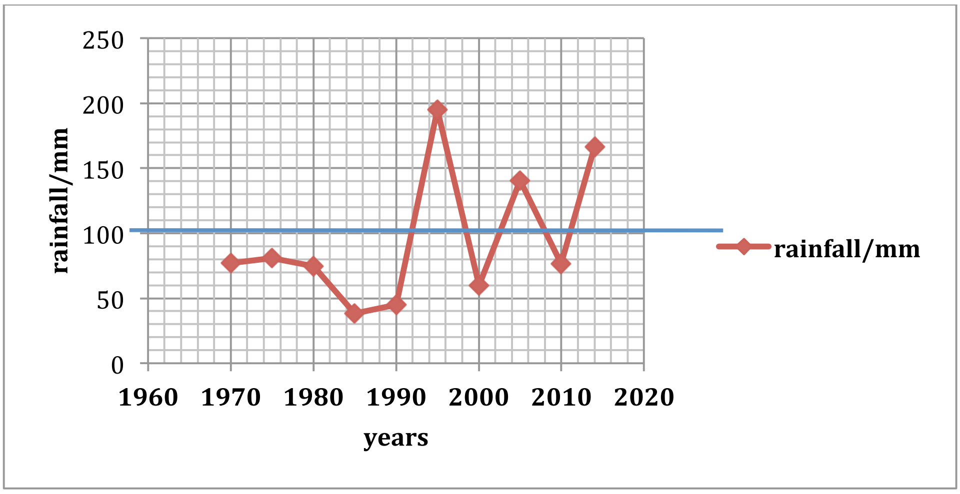

Figure 5

Fluctuation of Total Rainfall in the Study Area

Human Factors

As said by Noordwijk (1984), in a period of 17 years between (1955 and 1972), a zone of about 100 km wide between the desert frontier and the semi-arid land has become desert as a consequence of human activities and one of the most important factors that have degraded the natural vegetation cover of the study area is the human inference including the following:

The open-grazing system is practiced in the study area, which entails the communal use of natural grass land by any number of tribes. The number of animals which normally graze on the rangelands is not controlled by anybody and the nomads compete for good grass in the limited area that belongs to all of them. In the rainy season, the vegetation in wadies is recognized to be very dense and covers huge area, but in the dry seasons it is harmfully destroyed by overgrazing. Heavy overgrazing tends to be more profound increases of annual forage species and less for the perennials (Siha) and shrubs species. Perennials respond to out of season rains, provide re-growth after burning, and grow more quickly at the beginning of the wet season. However, annuals can be grazed more intensively, particularly in dry seasons than other species. So the surface is left bare with the exception of some dotted perennials and shrubs that could stand both drought and heavy grazing. Over grazing leads to deterioration of the carrying capacity by averting regrowth and by trampling which diminish the penetration of rain water into the soil. As grazing pressure rises, the less palatable species (Ushar) will bear the brunt of grazing pressure and their number will decrease and if excessive grazing continues, the population level of even these species will ultimately depress. It can therefore be concluded that the vegetation composition in the study area has undergone rapid and significant changes during the drought periods.

Over cultivation, results in a great deal of land clearance and removal of the natural vegetation for growing crops, in areas where a good crop is promising only in remarkably wet years and then soil remains bare for long time or for consecutive years. Accordingly, this way of cultivation causes reduction of the total area of natural vegetation cover and may contribute to fertile soil erosion. In addition to this, the nomads and many residents in the study area cut tress to build houses and animal enclosures or to use for fire wood and also they use the green branches or whole tree to feed their animals. Moreover, resettle policies of many pastoralists to take advantage of infrastructure and social services, have led to more stress on pastures, as well as water points are often established without taking into consideration traditional migration routes which sometimes be the cause of land degradation in the surrounding lands because they may lead to deterioration of soil and vegetation cover due to overstocking in the small area surrounding the water points.

The migration and displacement of rural population seeking better living condition in urban areas resulted in increasing of the total population of Khartoum State. Many of the new extensions of residential areas of Khartoum State are planned in Sharq Alneel locality. most of the residential areas increased at the expense of natural vegetation causing pressure and misuse of natural resources represent in cutting down of tress to use them as building materials and fuels.

Conclusions and Recommendations

The primary objectives of this study were to identify and detect land cover changes and their driving forces in the study area testing remote sensing techniques as baseline tool. The amount of data available for this study was effectively employed for monitoring and mapping the prevailing conditions of the study area.

Four land cover classes were identified using supervised and post classification methods which produced the best results. All what have been observed and proved by satellite images analysis throughout this study indicated that there is a high rate of changes of all land cover types of the study area, thus, the study illustrated that remote sensing technique and its tools is important technology for temporal analysis and quantification of spatial phenomena which is otherwise not possible to attempt through conventional mapping techniques. Change detection is made possible by this technology in less time, at low cost and with better accuracy. Change detection analysis revealed that bare lands, agricultural areas and residential areas increased during 1995–2015 resulting in substantial reduction of natural vegetation cover. The increase in bare land was significant it increased from 2744 km^2 in 1995 to 4454 km^2 in 2015 with rate of change reached 62%. However, the natural vegetation cover faced a severe decline it decreased from 5156 km^2 in 1995 to 2710 km^2 in 2015 by rate of change about 47% during the study period. The major negative outcome associated with the decrease in natural vegetation cover is land degradation. Results from the combination of the observed climate data and remote sensing data augmented with the answers of many respondents of the study area, indicated that the climate variability and fluctuation of rainfall amount have been occurred. In addition to this people have good awareness about the degradation processes of the natural vegetation cover, but many of them specially the pastoralists were of the opinion that the main causes of the land degradation were linked mainly to droughts and rain fall variability; they do not consider their activities (overgrazing, over-cultivation, and deforestation) as the main cause of changes. Vast areas, like Sharq Alneel Locality, that have most of the natural pastures of Khartoum State, need proper monitoring and consecutive assessments of natural resources from specialized authorities. The fiscal weakness of the state and lack of concern among the planners and lack of funds are to be considered as factors that force people to abuse their environment which is the basis of their lives.

According to the above mentioned it can be said that this results approved the objectives of the study. The results of this study would be helpful to plan and implement important management decisions in order to conserve the natural resources from depletion. The envisaged changes in the study area are very profound and demand rigorous scientific verification. Therefore, it is recommended that:

- A multi – professional team to be assigned to carry out further comprehensive research to limit the progress of these changes.
- Remote sensing techniques are a viable means of obtaining safe, low-cost and accurate information on vast areas, so a variety of methods have been implemented on continuous basis to detect and assess vegetation cover change in semi-arid areas with varying degrees of success on providing information for land use management.
- Capacity building and training to raise awareness of local communities in conservation, rational utilization and sustainable management of natural resources is an important need.
- As the vegetation cover is well developed in seasonal water courses, the improvement of water harvesting and spreading techniques to achieve rehabilitation of vegetation cover along the floods of these seasonal water courses is highly recommended.
- Establishment of shelterbelts and windbreaks by cultivating native desirable species to avoid the wind erosion and to protect the study area from desert encroachment.
- Reduce the planning of new extensions at the expense of natural resources.
- Arresting the ongoing degradation of natural pastures by applying rotation grazing system.

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