

Deterioration of blue Nile forests and its ecological effects in the Gezira State– Sudan

Abstract

The research aims to outline the major characteristics of forest cover in Greater Wad Madani and South Gezira Localities including the areas around the Blue Nile in the period 1973-2019 and analyze the apparent spatial and temporal attributes pertaining to species density, frequency and abundance and the causes of its deterioration and the impact of this deterioration on the ecosystem of the study area. To achieve these aims, digital data from satellite images taken by the U.S Land sat 5 and Land sat 7 for the years 1973, 2001 and 2016 were processed and analyzed using Erdas Imagine, Arc Map and GiS, whereby a quantitative and qualitative inventory of the forest cover is carried out using the square method to determine the percentage of coverage, density and abundance of tree species. The inventory showed clearly that diversity of tree species underwent clear decimation. Some species that were prevalent in the past became at the present few and rare such as *Acacia nilotica*, *Acacia seyal vor seyal* and *Acacia nubica*. Some of the species almost disappeared such as *A.seyal vor fistula*. Noteworthy, the *Prosopis juliflora* and *Capparis decidua* are beginning to be dominant unless measures are taken to combat their spread. An important indicator of the deterioration of forest cover is the decrease in the area of forests. While the forested area in the Locality comprised 14.7% of the total area of the study area in 1973 it decreased to 3.1% in 2016. The main reasons behind this deterioration were the need of the population for wood for fuel purposes, construction, traditional industries and grazing. The research raised several recommendations which include the preparation of a comprehensive environmental database on land use which must include the forest cover in addition to establishment of an administrative monitoring and follow up organ equipped with modern technology to ensure the sustainable conservation of forests.

Keywords: deterioration, forest, ecology, acacia, coverage, density, frequency, abundance

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Introduction

There are several studies on estimates of the area of forests in Sudan bearing in mind that since early 1900s extensive areas of woodland and forest have been converted to agricultural use.¹ Although Sudan used to have a large quantity of natural forest, studies have shown that by 1991 a large part of these forests remained almost unexploited.² In the late 1970s, FAO³ estimated that the country's forests and woodlands totaled about 915,000km², or 38.5% of the land area. However, the Department of Forestry Management in the Gezira State in the mid-1970s, reported that the total forest cover was only 584,360km², or 24.6% of the country's land area. More than 129,000km² (25%) of this estimate were located in the dry and semi-arid regions of northern Sudan. These forests were considered valuable chiefly as protection for land against desertification and served as a source of fuel for pastoral people living in the regions.⁴ However, the growing population pressure on the land resulted in an accelerated destruction of forestland and prompted steady encroachment of Sahara sand towards the south at a rate of about 10km/year in the 1980s.⁵ Noteworthy, since 1983, the civil war virtually halted forestry production in southern Sudan, from which came the overwhelming amount of forestry products.⁶ Similarly, the *Acacia* belts of the Nile were used intensively resulting in a rapid advance of deforestation.⁷ In 1990-1991 plans were underway to establish a forestry resource conservation project⁸ for the improvement of the running government forestry conservation and management policy and the issue of land

use making use of several funds from international development agencies. In, 1983 the National Forestry Administration reported that the forestry area was 96Million Km². The level of destruction can easily be noticed when this report is compared to the study of Bayoumi⁹ which indicated that the area of natural forests cover was 584,000km² in 1968 and then decreased to 559,000km² in 1980 and the report of World Bank (1986) which estimated the area to range between 18% and 23.4% of the total area of Sudan.¹⁰ On the other hand, Abdel Magid¹¹ estimates that the forestry area in Sudan in 1990 at 429,76 hectares equivalent to 25.1% of the total area of Sudan while FAO³ estimated that the area of forest cover is 454km².

The study area

The study area lies between latitudes (14°, 20 and 14°, 33 North and longitudes 33°,26 and 38°,33 East and is bordered in the north by Hassahisa Locality and the Locality of Greater Wad Madani, the locality of South Gezira in the southern part of the State and in the west by the Locality of Manqel and South Sinner State and in the East by the Blue Nile . The total area of the study area is about 3214km² (Figure 1).

The geological setting of the study comprises three formations. On the top is the Gezira formation which covers about 80% of the study area, followed in some places by Basement rocks of Silurian age and in other places by the water-bearing OmRwaba formation which is a very narrow area near the Manqel Locality. The region lies within the

light Savanna climate with average rainfall ranging between 250mm in the North to 350mm in the South.¹²



Figure 1 Location of the study area.

Usually starting in June until the end of September with 70% to 80% of it falling during the rainy season and decreases significantly in

the dry season.¹³ Irrespective of small pediplains around rocky areas, the dominant soil type is clayey soils which cover about 81% of the area. Topographically, the study area represents a semi-flat or flat plain which gently slopes from the south to the north. The Blue Nile is the main artery to which surface water and seasonal valleys drain.

The total area of the Wad Madani Locality is 142,857.3 acres and forests along the Blue Nile cover an area of 5351 acres equivalent to 3.7% of the total area of Locality. In addition, there are other forested areas located near many small settlements (Figure 2). According to the Gezira State Forestry Administration (1995), there are also reserved and natural forests which cover not more than 3368 acres.

Methodology

The research is based on the analysis of three satellite images from the US satellite Land sat 5 and 7 for the years 1973, 2001 and 2016 (Figure 3) using GIS and Arc Maps. To facilitate the inventory process, two forests were selected from the study area, one representing natural forests and the other representing cultivated forests.

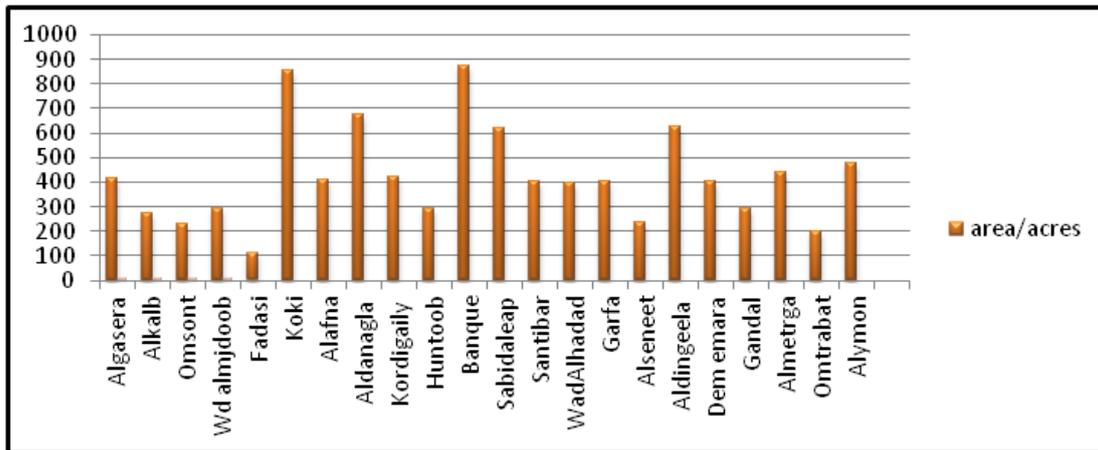


Figure 2 Forest area in the localities of Wad Madani and south Gezira.

Source: Information from Forestry Administration- Gezira State (1918).

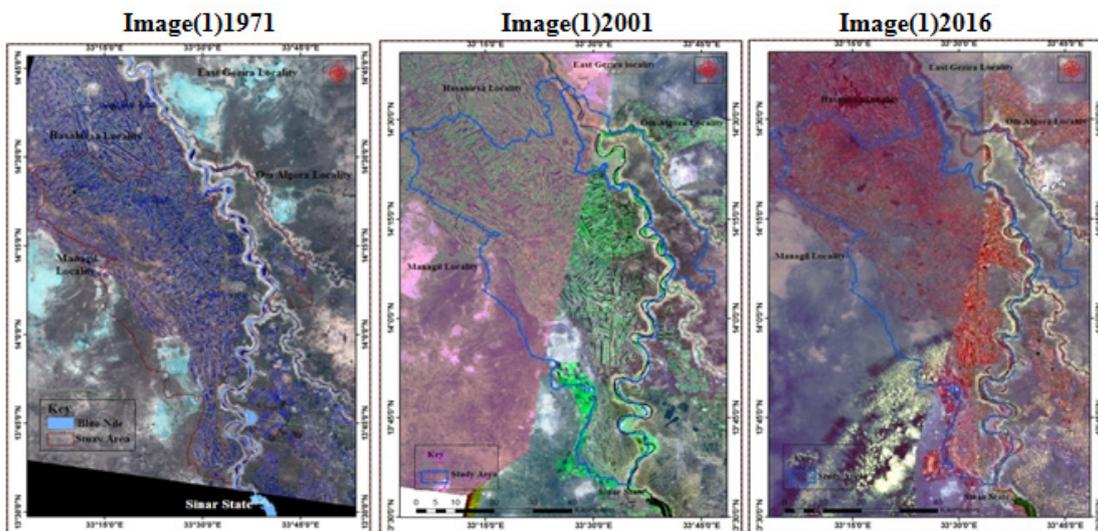


Figure 3 Images from the US satellite Land sat 5 and 7.

The data collected for inventory based on the quadrat method usually used in vegetation field surveys to determine the density, frequency and abundance of plant species. Accordingly, the selected forests were divided into squares, each 100m×100m, and from each square samples of trees were collected according to the following scheme:

Specify the sample box 100m×100m=10,000m².

- Identify a central location where the main and sub-directions of 8 directions.
- Selection of 10 squares from each forest separated by distances ranging from (2-3)km.
- Inventory of vegetation in accordance with the laws set for this (Table 1).

Table 1 Survey form that was applied to the study area

Species	S					N	Notes	L cm	C%	A%	F p/s	D p/s
	1	2	3	4	5							
<i>A. nubica</i>	3	-	7	-	5	15	-	30	60	60	5	5
<i>A. seyal</i>	5	-	5	5	-	40	-	15	45	80	10	10

Where S, square; N, number of total species; C%, coverage; L, plant length; F, frequency; A%, abundance; D, density; P, plant

Source: Gharaibeh, Al-Farhan, 1991.

Reasons for degradation of forest resources

According to the 1973 census, the population of Gezira State was 979,113, and in 1983 it increased to 1,117,840, and then to 2,715,605 in 1993.¹⁴ The latest population estimates carried in 2017 rendered a figure of 3,575,280 with a density of 137 per km². The field survey (2018), estimated that 100% of local people reported that until the year 1990 they covered their needs for firewood, home furnishing and traditional industries from nearby forests of villages and cities. However, this dependence decreased to 65% in 2000 and then to 47% in 2017, possibly because they started to resort to other emerging alternatives.

We find that the average consumption of a family (5-10 persons) is about 100 Kg of charcoal monthly, which is equivalent to 3 trees ranging in length from 3-5 meters, and has decreased to less than a tree at present in some areas. There were specific types of species that are usually felled more than others such as *Acacia nilotica*, *Acacia seyal var seyal* and *Acacia Senegal*. Of late, *Eucalyptus* as a cultivated species has entered to replace other species especially in building materials. The number of bakeries, which formerly depended on fire wood, has also increased, reaching 1171 in 2000, and began to switch to Gas and However, the unstable supply of Gas and electricity has recently forced the bakeries to return to the use of forest fuel again. The situation currently looks as follows: 55% of bakeries use wood, 3.5 electricity 26.5% use Gas.

Inventory of natural and cultivated forests

The results of the field work (2016-2017) indicated that there were more than four types of forests in the study area where 57% of the respondents stated that the forests species in their area were *A. nilotica*, and 22% *Eucalyptus* trees, 6% *A. seyal var seyal*, 13%

Determination of cover, frequency, density abundance ratios:

$$\text{Coverage} = \frac{\text{Number of one type of species}}{\text{Total number of species}}$$

$$\text{Frequently} = \frac{\text{Number quadrates where type (Acacia) is found} \times 100}{\text{Total number of quadrat studied}}$$

$$\text{Density} = \frac{\text{Number of species of one type (A)}}{\text{Total number of quadrat studies}}$$

$$\text{Abundance} = \frac{\text{Number of one type of species (A)}}{\text{Number of quadrat containing that species}}$$

A. seyal var fistula and 1% other species. The results of the field survey in (2018) are presented in (Table 2). (Local equivalents of Latin names of species are obtained from the Faculty of Forestry, University of Khartoum).

Table 2 Tree species in the cultivated and natural forest

Scientific name	Local name
<i>Acacia nilotica</i>	Sunut
<i>Balanites aegyptiaca</i>	Higleeg
<i>Acacia mellifera</i>	Kiter
<i>Acacia nubica</i>	Laot
<i>Capparis decidua</i>	Tundub
<i>Ziziphus spina-christi</i>	Sider
<i>Acacia seyal var fistula</i>	Talh
<i>Acacia senegal</i>	Hashab
<i>Acacia albida</i>	Haraz
<i>Acacia tortillis var raddiana</i>	Seyal
<i>Eucalyptus</i>	Ban
<i>Prosopis juliflora</i>	Miskit

Source: Field Survey (2018)

Quantitative inventory of natural and cultivated forest trees

Table 3 shows the quantitative inventory of species in the cultivated forests which are forests of *Eucalyptus* trees while Table 4 shows the values of trees in the natural forest in which *Acacia nilotica* dominates. We will outline first the different values of the prevalence of these species in terms of coverage, frequency, density and abundance and then compare these values with the forest cover in the past based on satellite images for the years (1973-2001-2016) and field survey (2018) to find out the quantitative and qualitative differences between them as follows:

- i. Species in the table above are found within the cultivated forest, which is originally a forest consisting of *Eucalyptus* trees.
- ii. We note that the *Acacia nilotica*, *A.nubica*, *A.mellifera* and *Balanites aegyptiaca*, are the most dominant
- iii. It is clear that the least dominant trees are *Capparis decidua* with a cover of 3.3%, and the abundance of 3.1 P/S, and density of 2.2 P/S, followed by *Ziziphus spina -Christi* with a coverage of 1.6%, and abundance 1.8 P/S, density 1.1 P/S, followed by *A.seyal var fistula* with 9.5% coverage, abundance of 10.6 P/S, and density 6.4 P/S, followed by *Acacia seyal vor seyal* has a cover of 1.5%, abundance of 2.5 P/S, and density of 1 P/S.
- iv. We note that the cover in *Capparis decidua*, *Ziziphus spina-Christi*, *Acacia seyal vor fistula* do not exceed 5%, except for *Acacia seyal vor seyal* where the coverage rate was 9.5%.
- v. In reference to field work (2016) the respondents mentioned that the dominant tree species in the study area are *Acacia nilotica*, *Acacia seyal var fistula* (Table 2 shows the presence of other species in the study area in 2017).
- vi. The presence of these species in the cultivated forest despite the prevalence of *Eucalyptus* is evidence that they existed in the past.
- vii. The presence of this cluster of trees is evidence of the diversity of trees .This is confirmed by satellite images for the years (1973, 2001 and 2016).

From Table 4:

- a. The tree species in the table above are found in the natural forest, which is originally an *Acacia nilotica* forest.

Table 3 Quantitative inventory of trees in cultured forest

Scientific name	Local name	Density P/S	Abundance P/S	Frequency %	Cover %
<i>Acacia nilotica</i>	Sunut	22,4	22,4	100	33,3
<i>Balanites aegyptiaca</i>	Higleeg	13,8	13,8	100	20,5
<i>Acacia mellifera</i>	Kiter	7,3	7,3	100	10,8
<i>Acacia nubica</i>	Laot	13	13	100	19,3
<i>Capparis decidua</i>	Tundub	2,2	3,1	70	3,3
<i>Ziziphus spina -christi</i>	Sider	1,1	1,8	60	1,6
<i>Acacia seyal var fistula</i>	Talh	6,4	10,6	60	9,5
<i>Acacia senegal</i>	Hashab	1	2,5	40	1,5

P, plant; S, square

Source: Field Survey (2017)

- b. The most dominant trees are *Acacia nubica* with 36.9% coverage and an abundance of 51.6p/s and density of 25.8p/s, followed by *Capparis decidua* with 33% coverage, and 46.2p/s and a density of 23.1p/s. We note that the species *Acacia nubica*, *Capparis decidua* and *Acacia tortillis* exhibit a frequency of almost 50%, while that of the rest is less than 50%.
- c. A noticeable scarcity of *Acacia albida*, *Ziziphus spina- christi*, *Acacia seyal var seyal*, *Balanites aegyptiaca*, *Acacia mellifera* and *Prosopis juliflora* with coverage not exceeding 5% except for *Acacia seyal var fistula* which is 7.6%.
- d. The presence of all these species of low prevalence in the forest is evidence of the diversity of forest cover in the region. However, it must be noted that species diversity was more pronounced in the past in terms of quality and quantity as determined by the fieldwork 2016.

In comparing the model of the cultivated forest in (Table 3) with the natural forest in (Table 4), the following attributes can be identified:

- i. Multiple species of trees in the cultivated forest and natural forest exist despite the rule of one species.
- ii. The species in the natural forest, such as *Acacia tortillis*, *Acacia albida*, *Prosopis juliflora* are rarely found in the cultivated forest.
- iii. The species *Acacia tortillis*, *Acacia albida* and *Prosopis juliflora* exhibit less cover and spread in the natural forest than in the planted forest.
- iv. The natural forest exhibits less density and less abundance in tree species than in the cultivated forest.
- v. The prevalence of trees in the past was very low.
- vi. The scarcity of the spread of some species in the past to less than 0.7% cover such as *Acacia mellifera*, with a cover of 0.6%, *Prosopis juliflora* with a cover of 0.4% and other species for 1% .
- vii. The emergence of exotic trees that have the ability to compete and spread but with low nutritional value such as *Prosopis juliflora* which demands urgent efforts to halt their spread.

Table 4 Quantitative inventory of trees in natural forest

Scientific Name	Local Name	Density	Cornucopia	Frequency %	Coverage %
<i>Acacia nubica</i>	Sunut	25,8	51,6	50	36,9
<i>Capparis deciduas</i>	Tundub	23,1	46,2	50	33
<i>Acacia tortillis</i>	Seyal	11,7	23,4	50	16,7
<i>Acacia seyal var fistula</i>	Talh	5,3	13,3	40	7,6
<i>Acacia albida</i>	Haraz	1,2	2,4	40	1,7
<i>Ziziphus spina- christi</i>	Sider	0,9	2,3	40	1,3
<i>Acacia seyal var seyal</i>	Hashab	0,8	2,7	30	1,1
<i>Balanites aegyptiaca</i>	Higleeg	0,5	1,7	30	0,7
<i>Acacia mellifera</i>	Kiter	0,4	4	10	0,6
<i>Prosopis juliflora</i>	Miskiat	0,3	1,5	20	0,4

Source: Field Survey (2017)

Changes in forest cover according to Land sat 1973

From the Land sat image of 1973 we note that the forest cover in the study area was dense and is occupying a large area of the total study area, (476,958km²) (Figure 4).

Forest cover in 2001

The forest cover in 2001 in the study area decreased in area. It reached 79.785km² (Figure 5). This is because of many factors. These factors include the practices of over-logging for fuel and construction in addition to overgrazing and lack of control from side of forest management.

Forest cover in 2016

Figure 6 shows that the forest cover in the whole study area in 2016 was 99,501km². It seems that at that time the level of awareness was high and the supervisory role of forest management was active and potent.

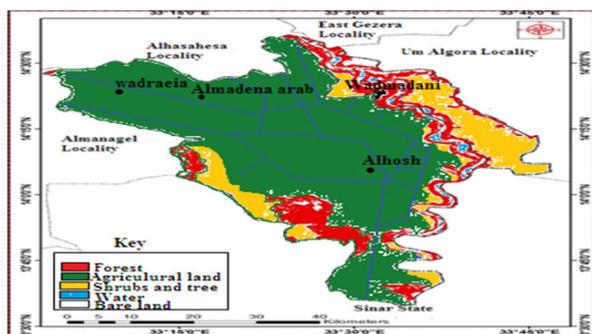


Figure 4 Forest cover in 1973.

Source: American Satellite Land sat 1973.

Changes in forest cover using GIS and remote sensing

Comparing the area of forests for the three periods (1973-2001-2016), we note that the forests in 1973 were dense and covered a large area. In 2001, the area shrank dramatically, while in 2016, it increased

slightly compared to what it was in 2001. We can conclude from this that there is density, distribution and cover area of forests show clear fluctuations. Nevertheless, the total lost area of forest cover in the study area amounted to 377.4569km²) (Table 5).

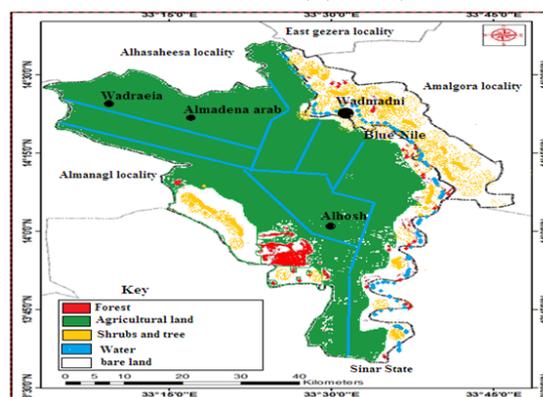


Figure 5 Forest cover in (2001).

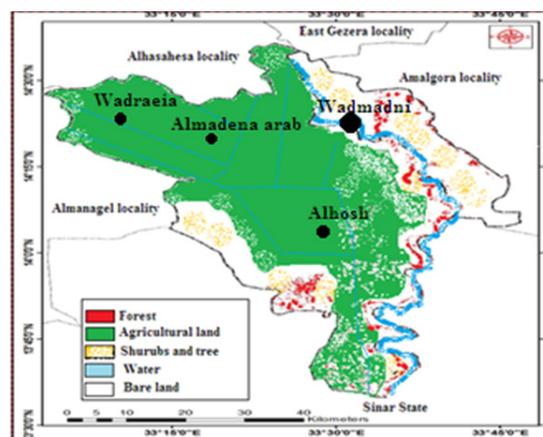


Figure 6 Forest cover in (2016).

Source: American Satellite Land sat (2016).

Table 5 Percentage of forest distribution for THE Years 1973, 2001 and 2016

Total area	Forests% 1973	Forests% 2001	Forests% 2016	Lost forests 1973-2016
476,958km ²	14.7km ²	2.5km ²	3.1km ²	377.446km ²

Source: analysis of American satellite images- land sat, 5-7

From Table 5, it can be seen that the area lost from large forests in 1973 was 397.1729km² which amounts to 14.7% of the total forest cover, while in 2001 it reached 2.5% and increased in 2016 to 3.1%. Recently, it can be seen that the forest area increased to 19,716km² despite the losses between 1973 and 2016 which amounted to 377,456km².

Changes in forest diversity

The forests in the study area were dense and varied and covered a large area. This was confirmed by satellite images for the year 1973 (Figure 2) and field work during 2018. Comparison of the two images reveals that there were more than ten species in the past which indicates that the forest cover was better than at present. However, the results of the inventory in 2018 (Table 3) confirm that the prevailing species at the present time are not more than 4 species. The most dominant species of present day in the study area are *Acacia nilotica* with a cover of 33.3% and abundance of 22.4P/S and density of 22.4P/S, although these values are decreasing because forest wood subjected to daily removal.

Economic and environmental changes resulting from forest changes

One of the results of the field work (2018) was that the forests in the study area are actually located and distributed along the banks of the Blue Nile and around villages and cities in distances ranging from 1-5km. These locations made forests accessible to the population who used for long times back to depend on logging them and collecting their products. Field surveys reveal that 43% of wood is used by the population for fuel, 34% of forest wood is of used in the manufacture of building materials, 32% in home furniture, 19.5% in traditional industries and 14.5% in other industries. However, this situation changed after the degradation of forests, where logging began to disappear and the dependence on forest products and forest-related professions became almost deserted.

The decrease in the biodiversity of trees and shrubs triggered a decrease in bird species. In the past, here were more than 25 species and the forests in the region formed an important sanctuary for migratory and seasonal birds. In addition, the removal and deterioration of forests, especially around villages and cities enhanced sand deflation and increased runoff. This is not to mention the significant reduction in recreational activities in which forests entertained a privileged place.¹⁵

Results

- Based on digital assessment of the forest cover in the study area in the period 1973-2016, it can be identified that the cover underwent some fluctuations. In the past, Images show that the forest cover occupied a larger area and was denser and the species variability was higher.
- Forests in the region suffer from decimation and environmental degradation. The proportion of forests in 1973 was 14.7%, in

2001 2.5% and in 2016 increased to only 3.1% of the total area of the region.

- Forest decimation and degradation is attributed to the reliance of population on forest wood to cover their needs on fuel, construction and traditional industries. However, the situation is expected to change as a result of prevalence of Gas and electricity.
- The decimation of forest cover affected the habitats and sanctuaries of birds, local and migratory, and reduced the value of forest as a recreation place for the population.¹⁶⁻¹⁸

Recommendations

- Forest legislations must be activated in order to protect forest cover from overgrazing, and indiscriminate logging.
- A comprehensive environmental database must be established for land use maps which necessarily include maps forest cover in order to assist decision makers and planners.
- Adoption of a program of follow-up using modern techniques such as remote sensing and GIS to ensure monitoring of changes and protection and conservation and development of degraded areas.
- Promotion of environmental awareness among the local population through various media.
- Achieving sustainable development in future forest-related development plans.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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