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THE ROLE OF GEOINFORMATION TECHNOLOGY FOR PREDICTING AND MAPPING OF FOREST COVER SPATIO-TEMPORAL VARIABILITY: DENDI DISTRICT CASE STUDY, ETHIOPIA

Berhan Gessesse Awoke

Department of Geography and Environmental studies, Kotebe College, Ethiopia

ABSTRACT

This study outlines the magnitude, rate and patterns of forest cover change over a period of 32 years using remotely sensed datasets with field work validation and integrated approaches of Remote sensing and GIS tools. Forest cover change detection is carried out based on the analysis of multi-temporal Landsat images using NDVI and Post-Classification Change Detection Algorithms. The result of the study revealed that a remarkable spatio-temporal variability of forest cover land is investigated in the district between the year 1973 and 2005. Forest cover land reduction by *80.15%* has been observed in the year 2005 as compared with the 1973 forest cover condition with a deforestation rate of 660.33ha per year. Moreover, the amount of forest cover change process is very significant along with areas having a gradient of less than 25^0 and elevation values of below 2,550m. Population pressure with related socio-economic factors like expansion of agricultural lands, demand of fuel wood and constructional materials are the major causes of forest cover change. Consequently, land degradation in the form of soil erosion, and declining of biodiversity seems to have reached a critical stage attributed through forest cover change process in the study site. In the light of this, the writer suggested corrective measures in harness with the problem of forest cover change and its environmental implication.

Keywords: Forest cover, GIS/Remotesensing, Change Detection, Dendi District, Ethiopia

INTRODUCTION

Land resources (soil, water and vegetation) are not managed properly in many developing countries and leading to various forms of degradation (Barrow, 2005). According to Rai, Sharma and Sundriyal (1994), the modern world has been facing considerable land resource degradation in the past few centuries. Forests, wetlands, grasslands and deserts have altered profoundly in area and in composition (Meyer & Turner, 1994). Besides, the vicinity of human settlement, agricultural lands, and the scale of timbering, mining, quarrying and other land use systems have grown enormously (Richards,1990).

Being a tropical country, Land use/Land cover (LU/LC) dynamics including forest cover change is one of the major environmental problems in Ethiopia. In relation to this, recent watershed based LU/LC studies show that land cover change is brutal and there has been agricultural land size expansion at the expense of natural vegetation cover lands and marginal areas without any appropriate conservation measures (Abate, 1994; Zeleke, 2000; Bewket, 2002; 2003; Amsalu, Stroosnijder, & De Graaff, 2006; Gessesse & Kleman, 2007; Assen & Nigussie, 2009; Hiale, Assen & Ebro, 2010). More specifically, the available information on forest cover land together with their changing status is very limited in Ethiopia. However, there were some efforts made to provide quantitative information about the forest cover change process of the country. Lots of researchers like Davidson (1988); Ethiopian Forestry Action Program [EFAP] (1994); Ezra (1997); Hamito (2001) & Ministry of Agriculture and Rural Development Sustainable Land Management [MoARDSLM] Secretariat (2008) widely reported that at the beginning of the 20^{th} century, 40% of the highlands of Ethiopia were covered with forests. The same studies signify that the forest cover around the end of the 20^{th} century is estimated to be less than 3%.

Closely associated with this, the forest cover land in Dendi District has been declining as of the beginning of the 20^{th} century. In this regard, Consultants on Natural Resources Assessment and Sustainable Development [CNRASD] (1999) observes that the Chilimo-Gaji and other nearby remnant of natural forest reserve (found in the district) has been under serious destruction and, therefore, has reduced in its areal extent as well as productivity. However, there is no document that indicates the necessary information in quantitative terms like the extent, rate and patterns forest cover changes. It is known that information regarding to the status of natural resources and environmental change is essential to detect, predict and monitor the changes as well as to conserve and manage natural resources (Hellden, 1987). To address these issues geo-information technologies and change detection methodologies have developed during the last five decades with forest cover change detection application take in hand through earth observation satellite data and decisions support tool of Geographic Information System (GIS) (Aronoff, 1989; Burrough, & Mc Donnel, 1998; Heywood, 2002; Lo and Albert, 2005; Scally, 2006; Lellisand, Kiefer, & Chipman, 2006). In light of this, LU/LC change detection analysis can be carried out using two or more dates of remotely sensed datasets (Mas, 1999; Lellisand, et al., 2006). Environmental change detection methodologies such as Post Classification Comparison Algorithms, Image Ratioing, Image Regression, On-screen Digitization, Principal Component Analysis and Multi-date Image Classification are developed by experts to apply in LU/LC change analysis (Jensen, 1997; Lellisand, et al., 2006). Among these, Post-Classification Comparison Change Detection method is found to be the most accurate procedure and presented the advantage of indicating the nature of environmental changes clearly (Mas, 1999; Yuan, Sawaya, Loeffelholz, & Bauer, 2005; Reis, 2008). Hence, geoinformatics tools such as Remote sensing and GIS techniques gives a vital contribution in providing information like the spatial extent and patterns of forest cover change over years and this information is decisive for environmental planning, monitoring and management strategies.

Therefore, this study is intended to generate knowledge and scientific information about the magnitude and rate of forest cover change in Dendi District over a period of 32 years using the integration of Remote sensing and GIS techniques that will help for decision making processes for sustainable uses of forest resources. Specifically, the objectives of this study are to (1) asses the magnitude, rate and patterns of forest cover change status (2) generate the year 1973, 1984 and 2005 forest cover map of the district (3) analyze the relationship between forest cover change and landscape attributes such as slope and elevation and (4) describe the possible causes of forest cover change and its environmental implication in the study district.

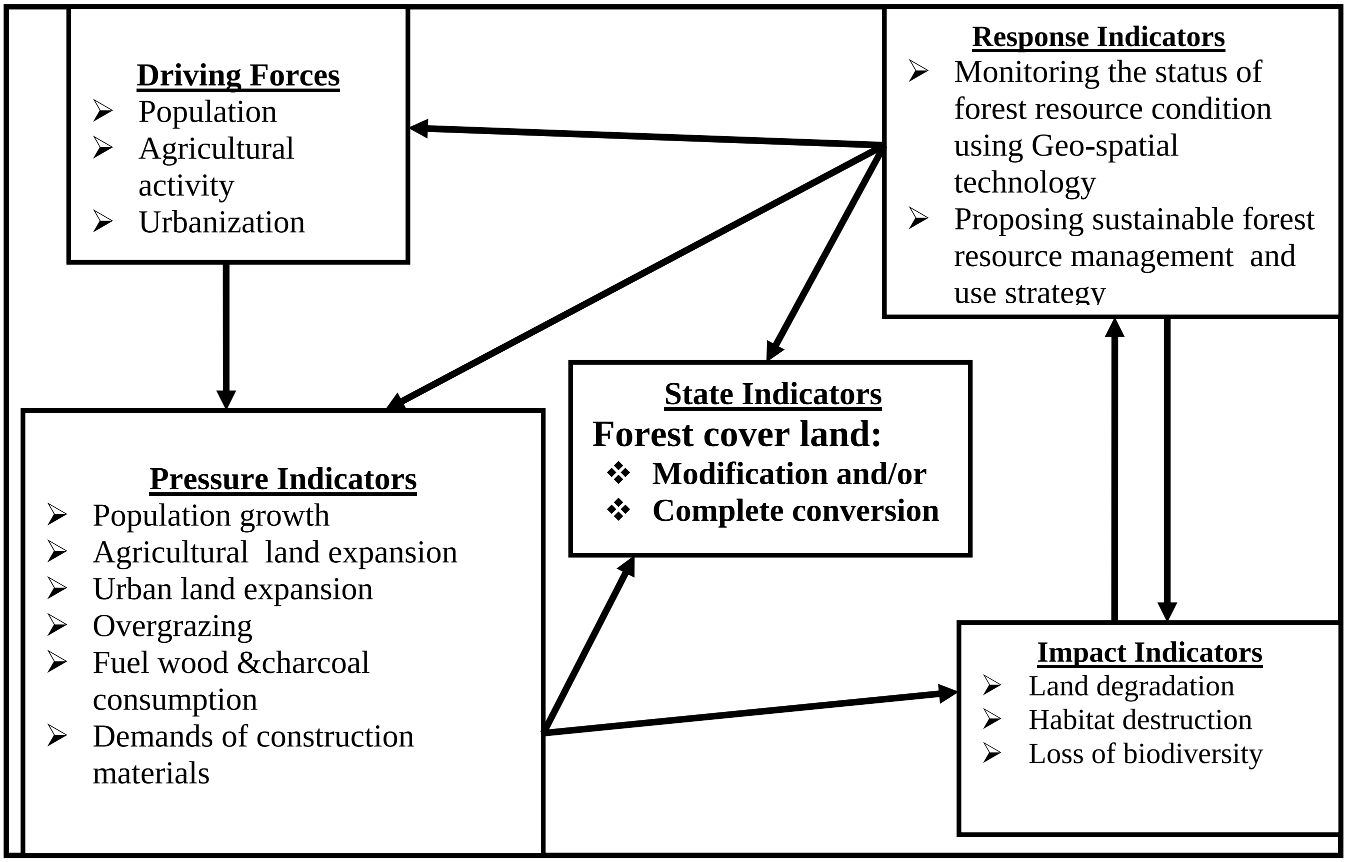
FOREST COVER CHANGE: A THEORETICAL CONTEXT

Forest, Its use and Cover change

Environmental resource degradation in general and forest resource deterioration in particular have been a major global issue these days. A schematic representation of conceptual framework on the nature, processes, causes as well as impacts of forest cover change is presented in Figure 1. And then this research is guided by Driving Forces, Pressures, State, Impacts, and Responses (DPSIR) model which has been adopted to identify for forest cover change problem and management options. This framework places forest resource degradation process in relation with society and the interaction among policies, the economy and management measures (Van Lynden, Mantel, & van Oostrum, 2004; World Bank, 2008). The DPSIR model is useful for evaluating the seriousness of deforestation processes, trends as well as for identifying potential sustainable forest management intervention strategies. At this day, people depend on the forest resources more than ever, mainly for their economic, environmental and enjoyment value. Wood from forest trees is used to make furniture and various hand tools (World Book Encyclopedia [WBE], 1994). Based on the works of Hamito (2001), wood obtained from the forest serve as the chief source of fuel for cooking and heating.

In spite of all these advantages, large portion of forest cover lands at global scale in general and in Ethiopia in particular have been modified and/or transformed in to other LU/LC classes. Forest cover change is a way in which the level of diversity and the density of individual species that make up dense vegetation structure are altered as a result of both natural and anthropogenic factors (WBE, 1994). Davidson (1988) also states that forest cover change involves the complete destruction of forest cover through clearing for agriculture, cattle ranching, small holder farming practice and large scale commodity crop production whether planned or spontaneous and their replacement by non-forest land use.

Figure 1: Theoretical framework adapted from Van Lynden et al., 2004, OECD 1993 cited in WB, 2006; 2008



Forest cover change is a continual process in Ethiopia. All research findings indicate that the aerial coverage of Ethiopia's forests and woodland resources have continued to decline due to the growing demand for cultivable land, grazing land, both rural and urban settlement expansion, fuel wood, commercial wood and building materials (Forestry and Wild life Conservation and Development Authority [FWCDA], 1982). In this regard, Pankhrust (1992) has confirms that there was no much forest as well as wood land during the medieval period in Ethiopia. This is because both urban as well as rural inhabitants rampantly cut down trees for their household uses (fuel wood, charcoal production, constructional and cultivated land expansion) purposes. Although estimates of forest resources of Ethiopia vary widely from source to source, literature confirms that for 35% to 40% of Ethiopia's land area was covered with heavy forests during the beginning of 20^{th} century. However, during the turn of the 20^{th} century the figure declined to below 3% with the rate of forest cover land conversion between 150,000ha and 200,000ha per annum to other land use systems and this situation threaten to eliminate the leftover forest lands within a short period of time (EFAP, 1994; Teketay, 2000).

Unchecked population growths along with related socio economic activities are the major contributing factors for the changing of forest cover land in Ethiopia. The immediate causes of forest cover change in the country are the need for farming and grazing land, the demand for fuel wood and construction materials, and repeated fire out break (Teketay, 2000;

Hamito, 2001). In addition, forests are cleared to acquire constructional materials, provide source of energy, make space for grazing, farming, building and layout infrastructures networks and to supplement raw materials such as an input for agricultural production and livestock grazing (Woldemariam, 1992; Ezra, 1997; MoARDSLM Secretariat, 2008).

The use of forest for traditional sources of energy is one of the major causes of deforestation in Ethiopia. Fuel wood accounts for the bulk of the wood used in the country and it is the fundamental domestic energy sources for people who are living both urban and rural parts of Ethiopia. Current official estimation of commercial wood operations assert that about 90% (21.6 million m^3) of the 24 million m^3 wood extracted annually is used for fire wood (20 million m^3) and charcoal (1.6 million m^3). The remaining 10% is used as construction, poles and other industrial requirements (Davidson, 1988). This shows that the use of forests for the source of energy has contributed for the rapid rate of forest cover change in Ethiopia. Consequently, land degradation, soil erosion mainly by water, declining of biodiversity, and shortage of fuel wood and constructional materials and unbelievable high cost of fire wood products are some of the major identified impact of this senseless destruction of forest resources in Ethiopia (Davidson, 1988; Teketay, 2000; MoARDSLM Secretariat, 2008).

MATERIALS AND METHODS

Description of the Study Site

Dendi District is located in West Shewa Zone of Central Ethiopia. The district lies within the coordinates from $8^0$43`North to $9^0$17` North Latitude and $37^0$47`East to $38^0$20` East Longitude and it covers a total area of 1,296.12 km^2. The altitudinal range of the district is between 1440 to 3260m a.m.s.l.

The climatic condition of the study area is mainly tropical in nature. According to Office of Finance and Economic Development for West Showa Zone [OFDWSZ] (2004) the study area is divided in to three traditional Agro-climatic Zones namely: Dega (temperate) (10%), Woina-Dega (sub-tropical) (60%) and Kolla (tropical) (30%). The annual average temperature of the study area is 17.5^0c. In addition, the area has an average annual precipitation of 1,225mm. Tamrat (1993) cited in CNRASD (1999) indicates that the majority of the soils of the study area were Vertisols black soils with characteristics of high clay content. Dendi District is covered with evergreen isolated forests with various types of vegetation such as higher trees, shrubs and ground cover grasses (Plate 1).

According to Central Statistical Agency [CSA] of Ethiopia (2005) the total population of the study district in the year 1996 and 2005 was 152,985 and 170,233 respectively. However, based on the population projection of the year 2010 the total population of the district is estimated to 186,398 (CSA, 2010). The high population growth is attributed to the favorable climatic conditions for both crops and livestock production, which attract a lot of people from outside the district. Agriculture is the back bone of the local communities' economy and about 89.6% of the district's population is engaged in this activity (OFDWSZ**,** 2004**)**.

Figure 2: Location map of Dendi District

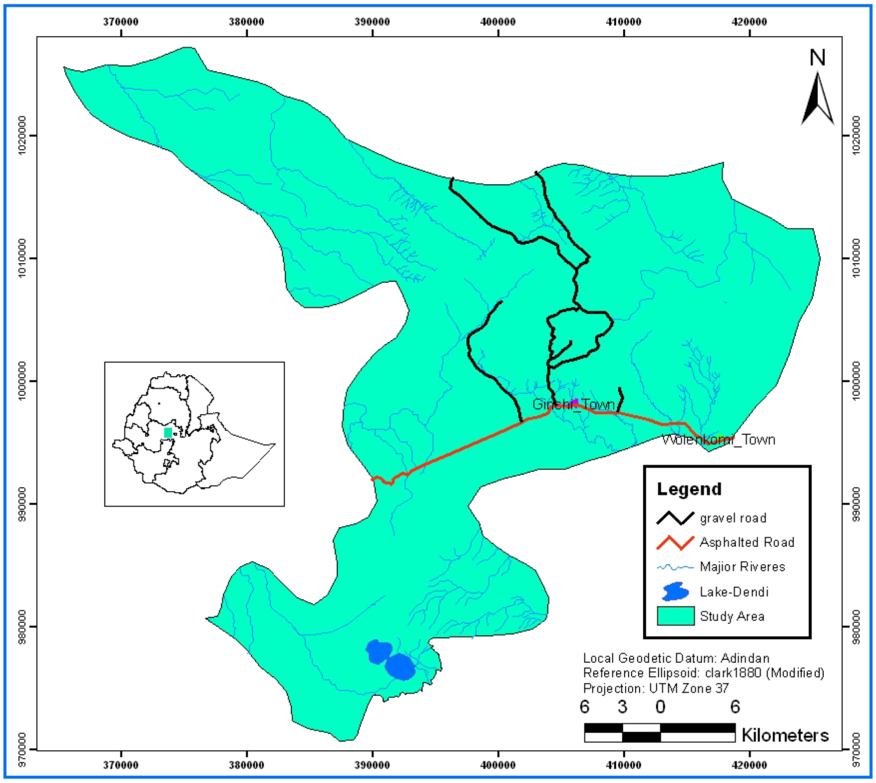


Plate 1: Dominant Forest Trees inside Chilimo-Gaji Forest Area, Dendi District (Photo by Berhan)

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In addition, forest exploitation and sale of forest products is also one of the major household income sources in the district. In the light of this, forest products such as constructional materials, fuel wood and charcoal are supplied to urban centers such as Welenkomi, Ginchi and Ambo Towns and even to the city of Addis Ababa from the existing forest resources in the district.

Data Sources and Materials

For this study, different datasets are organized and used from satellite imageries and topographic maps (Table 1). Moreover, the writer utilized ERDAS Imagine 9.1 and ArcGIS 9.3 software for image analysis and mapping purpose.

Table 1: Data sources and materials

I. Satellite Image Data					
	Sensor	Path	Row	Spatial Resolution	Date of Acquisitions
Landsat 1	MSS	188	54	57 X57 meter	31,January 1973
Landsat 5	TM	169	54	28 X 28 meter	22,November,1984
Landsat 7	ETM+	169	54	30X30 meter	26,November,2005
II. GIS Data					
Topographic maps of the year 1978 G.C having the scale of 1:50,000 were used for contour digitalization and Digital Elevation Model(DEM) generation The Etho- GIS data (used to generate District boundary)					
III, Software Used					
☞ ERDAS Imagine 9.1: used for Image analyses. ☞ ArcGIS 9.3: used for GIS analysis and mapping purpose.					

Methods

GIS and RS tools are used to analyze and quantify the spatio-temporal forest cover change in Dendi District. Procurement of best and available remotely sensed data is the initial stage for image processing in this study. In the mean time, Landsat images were used (Table 1). These images were digitally interpreted, analyzed and classified using ERDAS Imagine 9.1 software. Image rectification, re-sampling, interpretation and classification are the conventionally accepted image processing techniques employed in this study. Local geodetic datum of Adindan, reference ellipsoid of Clark1880(Modified) and projection type of UTM Zone 37 North are the spatial reference coordinate systems used in this study. From each sheet six ground control points were digitized to register the data sets with Root mean Square error of less than 0.47. Parallel to this, contours with 20 meter interval was digitized and Digital Elevation Model (DEM) was prepared from the digitized contours. Elevation and slope maps were derived from DEM data set using '*3D Analyst extensions' of* Arc GIS 9.3 software. In the mean time, geo-database was designed and all spatial datasets were stored within a geo-database environment to facilitate further analysis. Both unsupervised and supervised image classification techniques were performed. In addition, maximum likelihood supervised image classification algorithm is utilized to generate the LU/LC map of the district based on the remotely sensed data sets. However, in this study attention was given for forest cover change analysis and the three dates of forest cover maps of Dendi District were generated from the years 1973, 1984 and 2005 satellite imageries. To perform forest cover change detection analysis ‘Normalized Difference Vegetation Index’ (NDVI) and ‘Post-classification Change Detection’ methods were employed. To analyze the forest cover change processes in relation with landscape attribute of slope and elevation, the three dates of forest cover map of the study area was cross-tabulated with slope map of the study area using cross-tab module with the support of ‘Spatial Analyst Extension’ of ArcGIS 9.3 software.

NDVI Image Comparison and Change Detection Method

Various mathematical combinations of the Landsat channel 3(Red band) and channel 4(Near Infra red band) have found to be sensitive indicators of the presence and condition of green vegetation. Among these, NDVI is the most common index used to monitor the status of vegetation cover and forest vegetation biomass. According to Lillesand et al. (2006), the absolute value of NDVI for vegetation change analysis is between 0 and 1 and the NDVI empirical analysis is computed using equation 1.

Equation 1**……………..** $$NDVI = \frac{NIR(Band4) - R(band3)}{NIR(Band4) + R(Band3)}$$

Where, NIR=Image of Near-Infra Red, R= Image of Red

Post Classification Change Detection Method

Information about LU/LC change in general and forest cover change in particular can be obtained from remotely sensed data and/or by visiting the specific sites on the ground. The basic premises in using remotely sensed data for change detection analysis is that changes in LU/LC result in changes in radiance values which can be remotely sensed (Lillesand et al., 2006) and change detection involves the use of multi- temporal remote sensing datasets to discriminate areas of LU/LC change between two time period of imaging (Yuan et al., 2005, Reis, 2008). Therefore, the goal of change detection is to determine those areas on digital images that depict change features of interest (e.g. LU/LC change) between two or more image assessment (Brandon, 1998; Daniel & Steven, 2000; Mas, J.; Velazquez, A.; Gallegos, J.; Saucedo, R., Alcantare, C.; Bocco, G. et al,. *2004*).

Parallel to this, numerous change-detection techniques, ranging from simple image comparisons to spectral vector measurements have been developed. Regarding this Jensen (1997), Brandon (1998) & Lillesand et al. (2006) have reveal that one way of discriminating change between two dates of imaging is to employ Post-classification Comparison Change Detection Algorithm. In this method two or more dates of imagery are independently classified using remote sensing software. Moreover, Post-Classification Comparison Change Detection method provides where and how much change has occurred. In the mean time, the magnitude and rate of forest cover change also computed using equation 2 and statistics and change maps were compiled to express the specific nature of the changes between the dates of imagery.

Equation2……………….……

$$r = Q2 - Q1 / t \; x100$$

Where, r= Rate of Change

Q2= Recent year forest cover in hectare

Q1= Initial Year forest cover in hectare

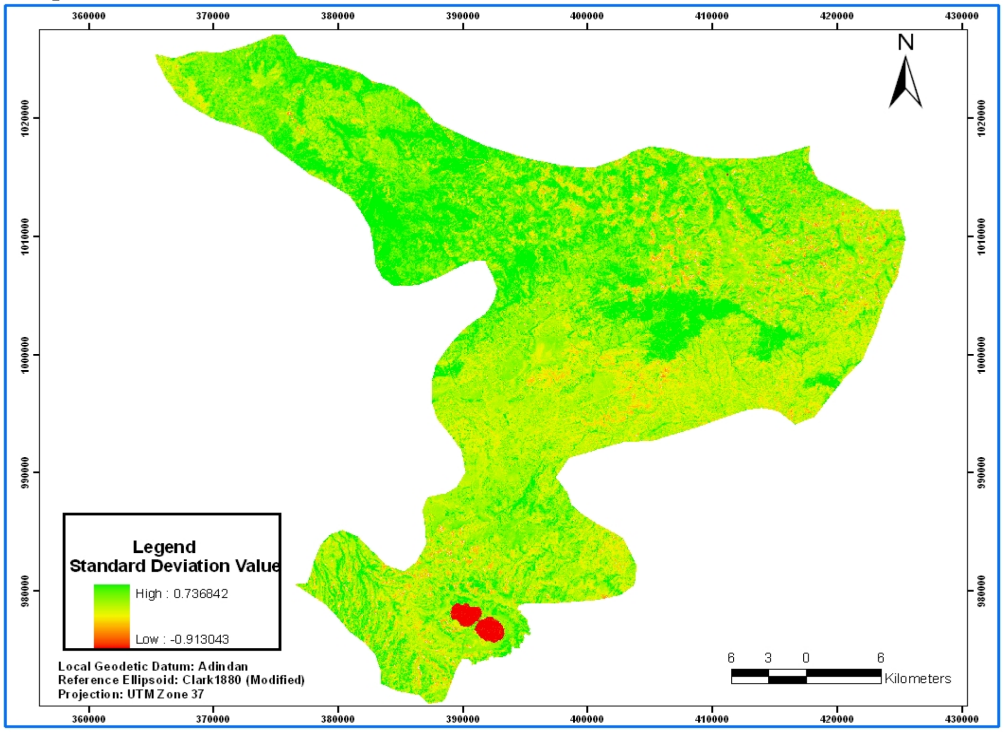
t= Interval year between Initial year & Recent year

RESULTS AND DISCUSSIONS

NDVI Image Comparison and Change Detection Result

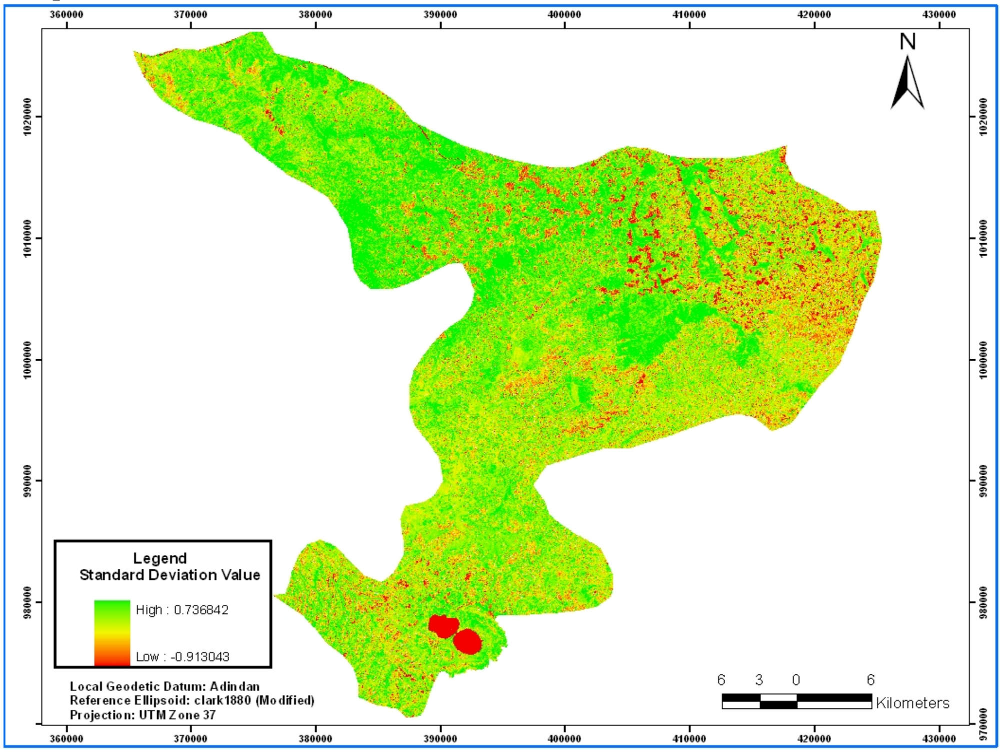
NDVI analysis employed in order to get an over view of the vegetation biomass change based on 1984 and 2005 satellite images in the study site. But the 1973 satellite image data was not considered in NDVI analysis due to the Near Infrared Band (Band3) is seriously affected by striping problem and unable to resolve this defect during image processing stage. The visual comparison analysis of the two NDVI maps (Figure 2 and 3) depict that there is a declining of vegetation biomass coverage in the study area from the year 1984 to 2005. This change argument is supported with the standard deviation value of NDVI analysis. The NDVI value is calculated using ‘equation, 1’ with the support of ERDAS Imagine 9.1 software. Then, the mean and standard deviation result is obtained within the ranges of 0 and 1 and following the statistical values of each of the images were presented in Table 2.

Figure 3: NDVI map of Dendi District



Source: The year 1984 Landsat image interpretation by the author

Figure 4: NDVI map of Dendi District



Source: The year 2005 Landsat image interpretation by the author

Table 2: NDVI analysis statistical values

Description	Year	
	1984	2005
Minimum	-0.64706	-0.80104
Maximum	0.73822	0.62613
Mean	0.097	0.05
Median	-0.0031207	-0.0043174
Mode	-0.0031207	-0.0043174
Standard Deviation	0.145	0.112

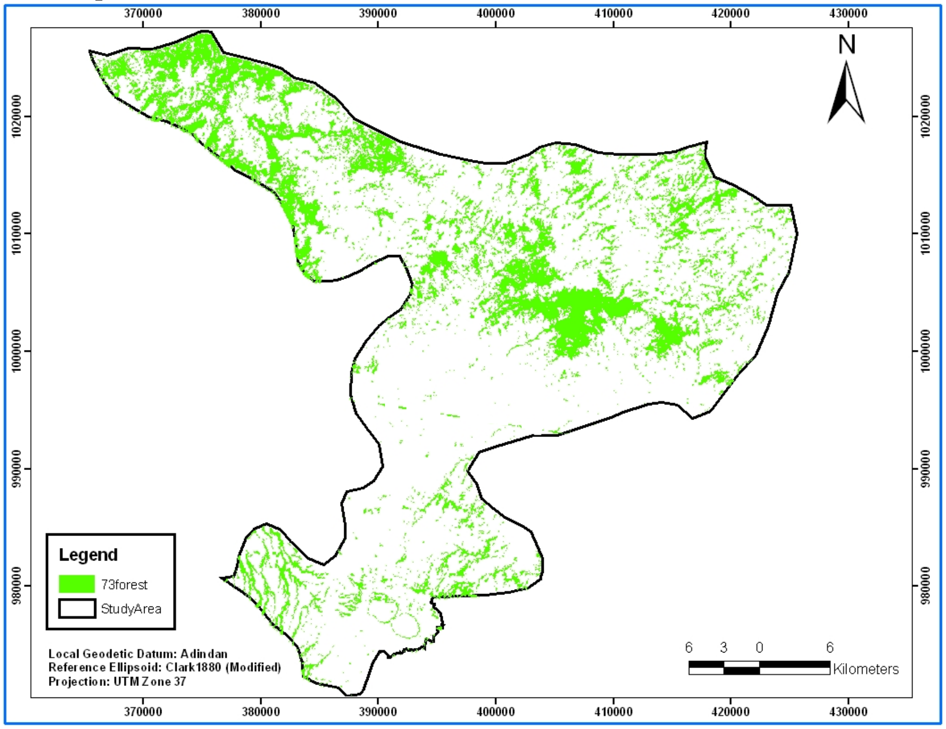
Source: Computed from the 1984 and 2005 NDVI maps (Figure 3 and 4)

As to vegetation conditions, the mean and standard deviation NDVI values vary from 0 to +1(Lillesand, et al., 2006). The computed value of the mean and standard deviation result is obtained within the ranges of 0 and 1(Table 2). As indicated in this table, the standard deviation value of the 1984 image is 0.145 which is a greater value as compared with the value of the 2005 NDVI image value of 0.112. This value shows that there is a declining of total vegetation cover change from the year 1984 to 2005.

Post Classification Change Detection Results

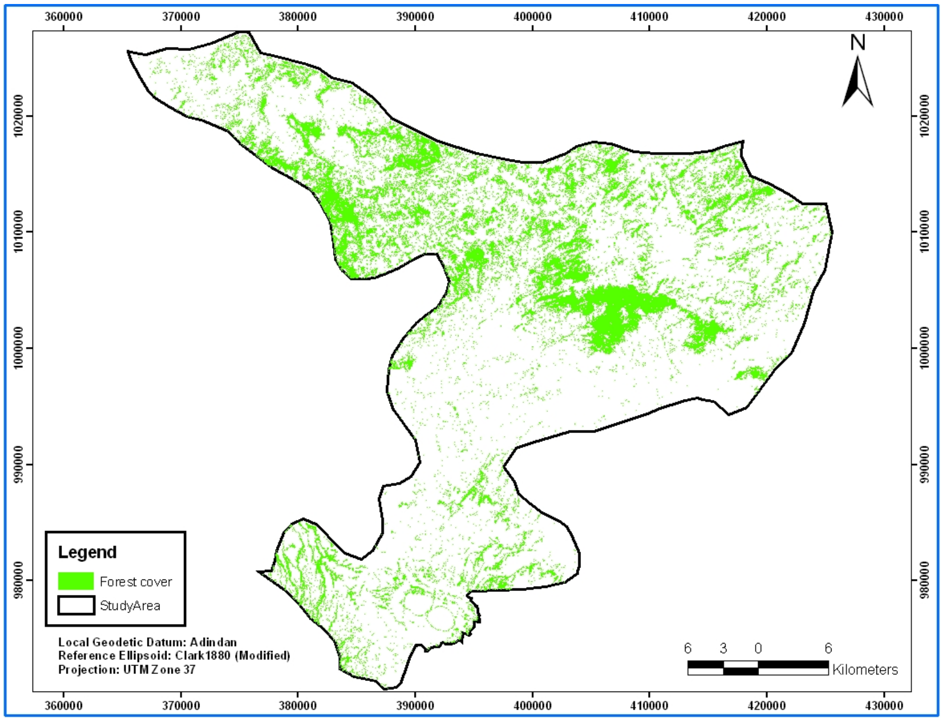
To point out forest cover change between 1973 and 2005, Post Classification Comparison Change Detection Algorithm is employed. During the analysis stage, digital satellite image interpretation of forest cover area for each year is performed and total area of the forest cover interms of hectare and its percentage were computed and summarized. Figure 5, 6 and 7 as well as Table 3 revealed that the magnitude of forest cover changes between 1973 and 2005.

Figure 5: Forest cover map of Dendi District, 1973



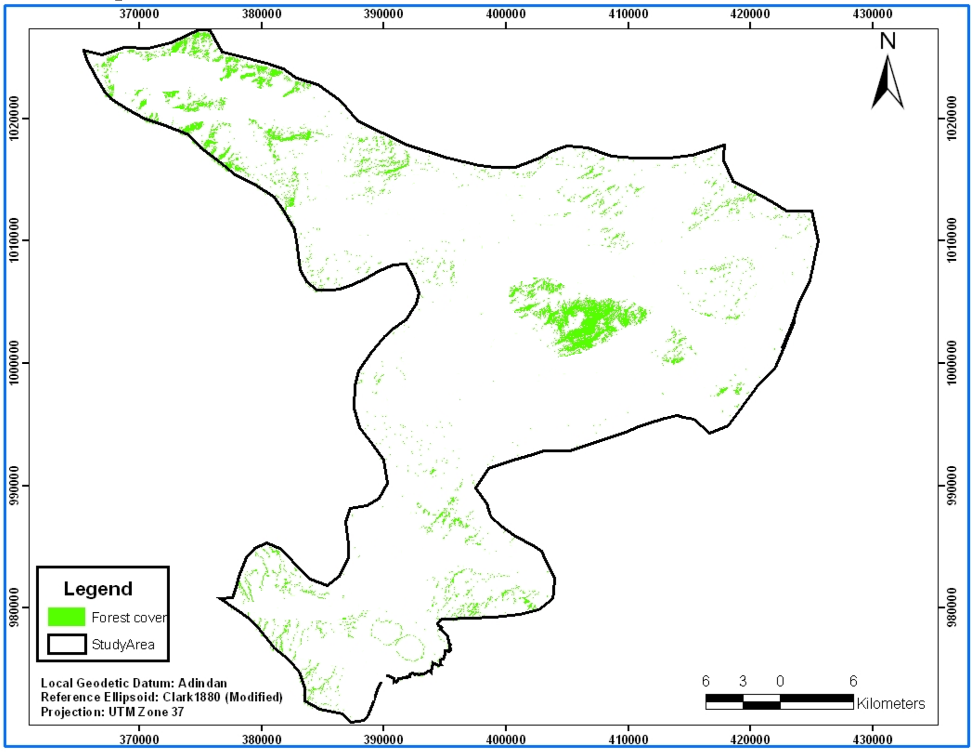
Source: The year 1973 landsat image interpretation by the author

Figure 6: Forest Cover Map of Dendi District, 1984



Source: The year 1984 Landsat image interpretation by the author

Figure 7: Forest Cover Map of Dendi District, 2005



Source: The year 2005 Landsat image interpretation by the author

Table 3: Total forest cover land area of Dendi District

Year	Forest Cover unit from the total area of the District (ha)	**Forest Cover (%)**
1973	26363	20.33
1984	25020.4	19.3
2005	5232.64	4.04

Source: Computed from the 1973, 1984 and 2005 forest cover maps interpretation by the author

About 26,363ha land of the district were covered with forest in the year 1973. Meanwhile, the forest cover land of the district is accounted for 25,020.4ha and 5232.64ha in the year 1984 and 2005 respectively. In the year 1973, 20.33% of the district was covered with forest resources while from the total area of the district about 19.3% was covered with forest resources in 1984. Later on, the forest land size declined in to 4.04% in the year 2005(Table 3). The rate of forest cover change also computed and the result presented in Table 4.

Table 4: Trends and rates of forest cover change in Dendi District

	Years			Rate of Changes		
	1973	1984	2005	1973-1984	1984-2005	1973-2005
Forest cover & loss(ha)	26363	25020.4	5232.64	-122.05	-942.27	-660.33

Source: Computed from the 1973, 1984 and 2005 forest cover maps interpretation by the author

The computed result (Table 4) shows that the average rate of forest cover change from year 1984 to 1973 is -122.06ha per year and from year 1984 to 2005, it was -942.27ha annually. Besides, considering the annual rate of forest cover change between1973 and 2005, the computed result is -660.33ha per year.

Patterns of Forest Cover Change

The pattern of change from forest cover to other LU/LC units between the year 1973 and 2005 is presented in Table 5. The result indicates the areal distribution of forest cover land and also gives information about what proportion of forest cover land transformed in to other LU/LC units during the respective time period.

Table 5: Patterns of forest cover change in to other LU/LC unites

Forest Cover Change	**B/n 1973 & 1984**		**B/n 1984 & 2005**	
	Area(ha)	%	Area(ha)	%
Forest to Water	35	0.27	16	0.09
Forest to shrub	5460	41.88	2636	13.96
Forest to Built up	577	4.43	355	1.88
Forest to Crop cover	5761	44.19	14582	77.23
Forest to Fallow Land	589	4.52	989	5.24
Forest to Grass land	123	0.94	113	0.6
Forest to Marshy/Grass	492	3.77	193	1.00
Total change	13037	100	18884	100

Source: Computed from LU/LC transformation Matrices (Appendix 1 and 2)

Based on the computed results (Table 5), 13,037ha of forest cover land are transformed into other LU/LC units' between1973 and 1984. Specifically, about 48.9% of the forest cover is changed into cultivated land (crop cover and fallow land) followed to shrub lands (41.9%). The remaining 3.77%, 4.43%, 0.94%and 0.27% of the forest cover land is transformed into marshy/grass cover, built up-area, grass land and water bodies in the same order. Moreover, between 1984 and 2005 about 18,884ha of forest cover land is changed in to other land cover units. The conversion of forest land to cultivated land takes the lion share (77.23%). The remaining 22.77% of the forest land is changed into other LU/LC units such as to water bodies, built up areas, shrub lands, grass lands and marshy with grass cover(Table 5).

Forest Cover Change With Respect to Slope and Elevation

Forest cover change processes in relation to landscape attributes have a certain importance to characterize the forest cover land of the area in relation with the various slope and elevation classes. It is also essential to see the distribution of forest cover land of the area and to investigate its changes along with slope as well as elevation class maps. In 1973, from the total forest cover land (26,363ha) about 51.5% was found to be within the slope gradient less than 25^0. Besides, roughly the same amount of forest cover (50.1%) also found in the year 1984 with slope value less than 25^0.

Table 6: Areal coverage of forest cover units by slope class at Dendi District

Slope	1973		1984		2005	
(Degree)	Area(ha)	%	Area (ha)	%	Area (ha)	%
< 3	3067.71	11.64	2754.43	11.01	329.61	6.30
3-8	66.6	0.25	39.05	0.16	0.43	0.01
8-13	1946.62	7.38	1525.2	6.1	2.73	0.05
13-18	1360.36	5.16	1281.88	5.12	72.63	1.39
18-25	7135.5	27.07	7103.36	28.39	1014.81	19.39
25-33	10065.93	38.18	9656.81	38.6	2515.71	48.08
33-56	2672.63	10.14	2613.11	10.44	1260.76	24.09
>56	48.41	0.18	46.56	0.19	35.96	0.69
Total	**26363**	**100**	**25020.4**	**1000**	**5232.64**	**100.00**

Source: Computed from the 1973, 1984 and 2005 forest cover maps and slope map (Appendix 3) of the district

Based on the year 2005 interpretation, from the total forest cover of the district (7,629. 38ha) only 20.19% of the study area is covered with forest resources having the gradient of less than 25^0 and the remaining 79.81% of the forest cover was found in areas having slope gradient greater than 25^0. In addition to this, the years 1973, 1984 and 2005 forests cover land of the district also analyzed along with the district's elevation range.

Table 7: Areal coverage of forest cover units by elevation class at Dendi District

	1973		1984		2005	
Elevation (M)	Area (ha)	%	Area (ha)	%	Area (ha)	%
1440-1687	1355.92	5.14	693.08	2.77	15.34	0.29
1687-1888	3520.18	13.35	1391.9	5.56	473.21	9.04
1888-2114	794.07	3.01	424.35	1.7	97.43	1.86
2114-2349	1717.29	6.51	1324.62	5.25	227.37	4.35
2349-2550	4277.79	16.23	3968.01	15.86	245.41	4.69
2550-2761	6170.95	23.41	6240.33	24.94	2143.31	40.96
2761-2929	5667.42	21.5	6818.58	27.32	1266.79	24.21
2929-3260	2859.49	10.85	4159.57	16.6	763.78	14.60
Total	26363	100	25020.44	100	5232.64	100.00

Source: Computed from the year 1973, 1984 and 2005 forest cover maps and elevation map (Appendix 4) of the district

The distribution of forest cover land unit along with elevation variation is presented with Table 7. In the year 1973, from the total forest cover area of 26,363ha, about 44.24% is found below the elevation 2,550m and the remaining 55.76% is found above 2,550m. Furthermore, in 1984 from 25,020.44 ha of forest cover land, 31.14% and 68.86% is found with elevation less than 2,550m and above 2,550m, respectively. From the remaining 5232.64ha of forest cover found in the district in the year 2005, about 20.23% found bellow 2,550m. The remaining 79.77% is found above the reference elevation boundary line.

Generally, in the year 1973, the vegetation cover of the area was greater than that of non-vegetated areas such as crop lands, water bodies, grass lands and built-up areas. Roughly vegetation cover of forest lands and shrub lands accounted for 51.43% of the total area of the district. But between the years 1973 to 2005 the proportion of vegetation cover mainly forest cover land was kept on declining trend. This is because in one way or the other, this cover class had the important source of change, to the other land cover and land use types. Moreover, the spatial distribution of forest cover across slope class is different between the years. When the slope gradient increases, the areal coverage of forest cover of the three years of interpretation also increases (Table 6). With respect to slope and elevation, the amount of forest cover change process is so significant along with areas having a gradient of less than 25^0 and elevation values of bellow 2,550 m. Thus, this output indicates that forest cover found relatively in gentle slope terrain and areas having an elevation of less than 2,550m, is being easily transformed in to other LU/LC units. This condition is also observed during field visit and it can be argued that the forest cover land of the district is marginalized into inaccessible steep slope areas, church compounds and isolated hills. Hence, the problem of forest cover change as well as destruction of forest resource is a critical problem in Dendi District.

CAUSES OF FOREST COVER CHANGE AND ITS ENVIRONMENTAL IMPLICATIONS

Causes of Forest Cover Change

Several factors stimulated by the activity of man are responsible for massive conversion of forest cover land into other land use /land cover units in Dendi District. Satellite image analysis and discussion with (Agricultural officers and household heads) summary report reveals that the leading causes of forest cover change in Dendi District is expansion of agricultural activities followed by fire wood and charcoal production, demands of constructional materials, settlement expansion and income generation(Table 8). As it has been explained in site description part, Dendi District is attracting large number of settlers because of its favorable climatic condition. The population is almost enlarged from 152,985 (1996) to 186,398 (2010). Population growth is the major factor which affects forest resources in the study area. The forces behind the forest cover change problem are partly population pressure as well as increased demand of various types of forest product such as fuel wood, building poles and making furniture as well as the people’s desire to obtain adequate agricultural lands. Based on the view of informants and field observation data, due to the alarming increase of the demand of forest products, both the natural and plantation forests which are grown in the district have been seriously depleted. In the developing world, increasing population size has two-fold impact on the forest resources. On the edges, sedentary cultivators are nibbling away in order to create more land to grow food, while in the forest itself the expanding numbers of shifting cultivators are forced to shorten rotations, leading to permanent change (Williams, 1990).

Table 8: Views of respondents regarding reasons for the decline of forest cover change in Dendi District

Perceptions	Agricultural officers		Household Heads		Total	
	No.	%	NO.	%	No.	%
Expansion of Agricultural Lands	4	50	17	56.67	21	44
Fire wood and Charcoal production	2	25	8	26.67	10	20
Demand of Constructional materials	-	-	3	10	3	8
settlement Expansion	2	25	-		2	4
Income Generation	-	-	2	6.66	2	16
Total	8	100	30	100	38	100

Source: Computed from field survey data

As discussed in the previous sections, the agro-ecological conditions of the district are convenient for agriculture. It has also noted that agriculture is the major livelihood of the study area population. Due to this, crop production and livestock rearing is the basic sectors of the subsistence production system and the products obtained used as supplementary food sources for peasants who are inhabited in the district. Table 5 and Appendixes 1 & 2 indicate that there is an increase of cultivated land coverage in the study district. The implication of increased cultivated land interms of areal coverage means other LC/LU units have been transformed into cultivated lands. For instance, between 1973 and 2005, about 20,525ha forest cover land is drastically changed into agricultural lands (both crop cover and fallow land). In addition, according to the views of respondents (44% with Table 8), the expansion of various types of agricultural activities in the study area is the major source of forest cover change. Therefore, the presence of farmers with their various types of farming activities (both crop production and livestock rearing) inside and along the margin of the district's forest cover land is considered to be the major factor for forest cover change in the study area.

The majority of the people in Dendi District are also depending on fuel wood as a source of energy (Plate 2). In the rural areas fire wood (collected from the nearby forest areas) and cow dung are the two most important sources of energy. According to the informants, over the recent years fire wood is commercialized as its demand has increased particularly in those areas which are devoid of trees and in the urban areas of the district. Even the district is the core supplier of charcoal and fire wood to both Ginchi and Welenkomi Towns (found in the District) and some amount of charcoal is even transported to the nearby urban areas mainly to Ambo Town as well as Addis Ababa City by illegal charcoal makers. Moreover, 28% of the respondents (Table 8) argue that fire wood and charcoal production are one of the major causes of forest cover change. Hence, the increasing demand of forest products, in the form of fire wood and charcoal within and outside the district has been causes of deforestation in Dendi district.

Plate 2: Loges of trees which have been cut down for fire wood production from the nearby Chilimo -Gaji forest reserve area and ready for selling in Dendi District (photo by Berhan)

The demand of forest products for the construction of house and fence has also aggravated the destruction of forest in Dendi District .From the respondents' point of view about (8%, Table 8); cutting trees to fulfill the demand of constructional material is considered to be the causes of deforestation in the district. Field observation data also indicate that woody biomass (plate 3) was found to be the single most important house construction material in the district.

Plate3: Poles of trees which have been cut down from the nearby forest areas and ready to sell for the purpose of house as well as fence construction, in Ginchi Town (Photo by Berhan,)

According to the view of agricultural officers most of the population of the district are poor and exposed for lack of adequate access to basic needs (such as food, clothing and shelter). However, huge proportions of dwellers in the district are engaged in different activities to supplement their living condition. Selling of wood and wood products are traditional way of working activity for the poorest people such as jobless youths and women fuel wood carriers who are living in the district. Referring to this, agricultural officers and forestry experts argue that these groups of people illegally cut down the trees from the forest area so as to supply a large quantity of forest products for urban dwellers and they sell it in small markets. Data obtained from field survey indicate large amount of loads of leave; tree branches and poles are carried by a number of people from different direction of forest areas towards Ginchi and Welenkomi towns.

Impact of Forest Cover Change

Currently, people depend on forests more than ever, especially for their socio-economic value. Despite all these importance, forest resource is mal-treated and deforested unwisely and the major environmental problems in the study area, which resulted from forest cover change, are discussed here under. To start with, land degradation resulted from unsustainable land uses such as over cultivation, deforestation, overgrazing, poor management and poor cultivation (MoARD Secreterite, 2008). Land degradation accelerates soil erosion, which is termed as the removal of loose surface materials and nutrient content by different agents mainly water and wind. Likewise, the mountainous site of the district reflects this reality and excessively degraded.

Plate 4: Gully development features, which leads the continuation of intense land degradation, near towards Boda Village, South of Ginchi Town in the study District (Photo by Berhan)

The relief feature of Dendi District is rugged with wide range of altitudinal variation (ranges from 1440 to 3260m).This rugged nature of topography coupled with high rate of deforestation and high intensity of summer rain fall results extensive gully formation as well as sever soil erosion. Besides, according to the view of agricultural officers of Dendi District, the vital role of forests due to forest degradation problem is strongly disrupted in the study area. In the mean time, runoff, flooding and rampant soil erosion is intense during rainy season.

On top of this, the geographical setting of Dendi District is a land of diverse and conducive ecological condition due to its wide range of altitude and relatively high amount of rainfall. As a result, the district was originally the land of many indigenous tree species such as Juniperus procora, Olia africana, Acacia abyssinica, Acacia nugri, Hagenia abyssinica and other valuable tree species to name but a few. However, one of the known indigenous tree species, for instance, Hagenia abyssinica (Plate 5), is over exploited due to selective cutting and is currently confined only in few inaccessible areas such as church yards and the hilly lands. This clearly shows that the exploitation of indigenous forests greatly affects the biological diversity of Dendi District. In addition, according to the interview held with elders, various types of wild animals used to inhabit the locality have now disappeared due to devegetaion of the area.

Plate 5: Hagenia abyssinica an endangered indigenous tree species, found in Chilimo- Gaji forest reserve areas of Dendi District (Photo by Berhan)

CONCLUDING REMARKS

The study demonstrates that remotely sensed datasets as well as geoinformatics techniques such as Remote sensing and GIS tools were an effective means for analyzing and mapping of the magnitude, rate, and spatial patterns of forest cover change. From the whole study it has been recognized that the forest cover change in the form of deforestation is one of the major land resource degradation problems noticeable in Ethiopia. The case study as presented in the study site is a typical example of how rapidly the forest resource is disappearing in Ethiopia. The situation in Dendi District shows that extensive areas of forestland have completely been deforested while some areas of the forest cover land have been considerably degraded. Many of the forestland areas have transformed into cultivated land or grassland with a few scattered trees and shrubs. Areas which were covered by dense forest lands in the early 1970s are now completely devoid of trees. Therefore, to protect the forest resources from further depletion the following feasible suggestions are forwarded based on the findings and the conclusions drawn. To use this precious resource sustainably, awareness creation campaigns especially for the farmers who are dwelling along the margin and inside the forest areas should be an obligatory assignment for the concerned bodies. Above all, there is a need for designing policies and strategies to protect the destruction of forest resources. This requires well-organized institutions to take responsibility for the conservation of forest resources. In addition, massive and concentrated effort should be exerted by various stakeholders, as well as the society at large that dwell in the study area in order to conserve, manage and use the remaining forest resources in a sustainable manner.

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Appendixes

Appendix 1: Matrix of Land Cover/Land Use Changes Between1973 and 1984 at Dendi District(Area in square kilometer)

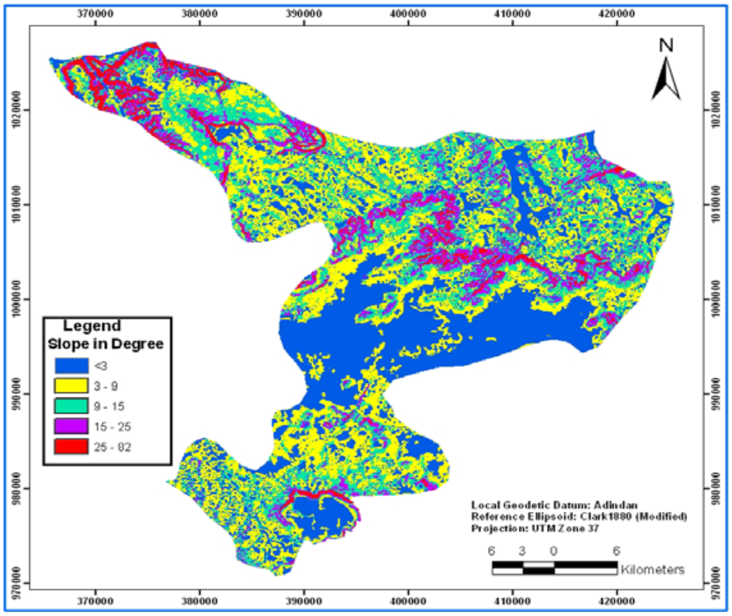
		Land Cover/Land Use Units of 1973								
Land Cover/ Land Use of 1984		Water Bodies	Forest Cover	Shrub Land	Built-up Area	Crop Cover land	Fallow Land	Grass Land	Marshy/grass	Class Total
	Water Bodies	6.45	0.35	0.07	0.02	0.06	0.03	0.04	0.03	7.04
	Forest Cover	0.42	132.3	62.22	1.22	4.68	17.88	14.3	16.7	249.82
	Shrub Land	0.07	54.6	120.56	5.47	20.33	70.19	39.86	25.31	336.6
	Built-up Area	0	5.77	17.19	6	10.76	13.2	7.38	2.56	62.95
	Crop Cover	0.1	57.61	123.73	23.11	64.26	85.91	47.71	20.61	423.36
	Fallow Land	0.01	5.89	26.21	2.37	5.95	32.43	14.53	4.4	91.86
	Grass Cover	0	1.23	10.01	0.42	2.83	9.83	4.75	1.66	30.74
	Marshy	0.01	4.92	42.41	1.39	1.74	19.46	6.78	17	93.75
	Class Total	7.07	263.63	403.7	40.15	110.93	249.76	135.74	88.52	1296.12

Source: 1973 and 1984 land cover/ Land Use Classification Maps

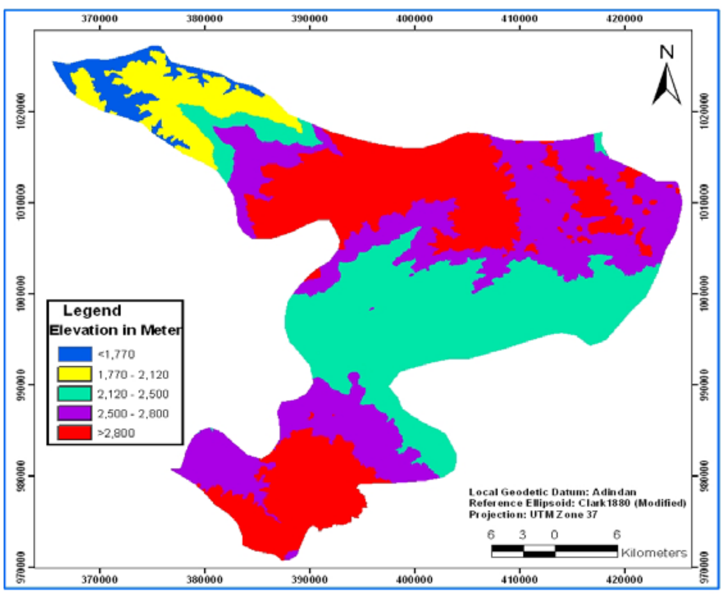
Appendix 2: Matrix of Land Cover/Land Use Changes Between1984 and 2005 at Dendi District (Area in square kilometer)

		Land Cover/Land Use Unites of 1984								
Land cover/Land use of 2000		Water Bodies	Forest Cover	Shrub Land	Built -up Area	Crop cover	Fallow Land	Grass Cover	Marshy/ Grass	Class Total
	Water Bodies	6.99	0.16	0	0	0.01	0	0	0	7.16
	Forest Cover	0.1	43.99	5.06	0.61	12.01	0.2	0.1	0.25	62.32
	Shrub Land	0	26.36	34.14	6.21	39.45	8.44	1.51	10.54	126.65
	Built-up Area	0	3.55	11.06	14.99	34.02	11.73	0.71	4.15	80.21
	Crop Cover	0	145.82	217.15	31.36	290.07	32.55	21.44	34.84	773.23
	Fallow Land	0	9.89	31.98	8.2	29.22	34.54	0.13	9.27	123.23
	Grass cover	0	1.13	14.62	0.38	6.1	0.68	4.4	1.24	28.55
	Marshy/ Grass	0	19.3	22.89	1.17	12.09	3.51	2.64	33.17	94.77
	Class Total	7.09	250.2	336.9	62.91	422.97	91.65	30.93	93.46	1296.12

Appendix 3: Slope Map of Dendi District



Appendix 4: Elevation Map of Dendi District



ABOUT THE AUTHOR:

Berhan Gessesse Awoke is a GIS and Remote Sensing Senior Analyst and a Lecturer in the Department of Geography and Environmental studies at Kotebe College, Ethiopia.