Assessment of Forest Land Cover Change and Its Driving Factors: A Case of Adaba-Dodola District, Ethiopia.

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Abstract: The magnitude and rate of forest cover change over the past 30 years in Adaba-Dodola district, Ethiopia have been investigated. The forest cover map based on land use/land cover of the area is generated by using remote sensing (RS) and geographic information system (GIS) techniques. The mainland use/land cover types have been identified as dense forest, open forest, grassland, agriculture, settlement, and water body after collecting and examining literature and information from interviews, field observation, and multiple sources. Moreover, digital data from the Landsat satellite images in the year 1988, 2003 and 2018 were employed.

The result of change detection analysis displayed that the area had substantial land-use/land cover changes in general and forest cover change in particular. Specifically, the forest cover land declined from 236,433 ha in 1988 to 202,127 ha in 2003 and 200,476 ha in 2018. The dense forest cover reduced from 45.93% in 1987 to 16.19 % in 2018. The rate of deforestation between 1988-2003 was 2287.1 ha per annum but it declined to 110 ha per annum in 2003-2018. The decrease in deforestation occurred after the establishment of integrated forest management project. The problem of forest cover change is directly linked with human activities including population pressure and socioeconomic drivers like the expansion of agricultural activities, demand of fuelwood and construction materials, as well as using such resources for income. Countermeasures to alleviate the forest cover change and its impact have been suggested.

Key Words: Land use/land cover change (LU/LCC), Adaba-Dodola District，Geographic information system, Remote sensing

1. Introduction

Land use denotes the human utilization of the land, whereas land cover indicates the physical state of the land. The two interrelated but different effects, land use and land cover change, may be the result of natural processes or human activities. Furthermore, technological advances and expanding population have put increasing pressure on scarce resources and have created a variety of complex land use dilemmas that affect persons at all levels of society. Land use/ land cover change (LU/LCC) has become a central component in current strategies for managing natural resources [1]. LU/LCC is an endless process taking place on the earth surface starting from ancient time. Expansion of agriculture to meet the demand of growing population such as food and fibre at the expense of vegetated lands is the most significant historical change in all parts of the world [2].

LU/LCC plays a major role in the study of global change. It may interact with deforestation, biodiversity loss, global warming, and increase of natural disaster-flooding. Both natural and human activities are responsible for LU/LCC [3], but the latter is increasingly recognized as a dominant force [4]. Human activities are responsible for the conversion and transformation of plentiful of the world's natural land covers [5]. For instance, over the last 10,000 years, about 50% of the ice-free land surface has been changed by human activities [2]. During the last 3 centuries, around 1.2 million km^2 of forest and woodland, and 5.6 million km^2 of grassland and pasture have been converted to other uses globally, while cropland has increased by 12 million km^2 [6]. It is also important to notice that LULC change is one of the challenges which powerfully influence the process of agricultural development and the food security situation in Ethiopia [7]. Being a land of great geographic diversity, Ethiopia is characterized by sharp and repeated environmental contrasts. There are areas where population pressure, in conjunction with a growing rural population and rising subsistence demand have contributed to the deterioration and depletion of the natural resource base. In the highlands of Ethiopia, the influence of human activity on the environment is so remarkable owing to intensive cultivation; land fragmentation, economic and political forces that relate to peasant agriculture. More than ever, the need for rational planning of land use/cover development and optimal use of the land resources is evident. That is why accurate and reliable data on land use /cover change and their trends are necessary for understanding local environmental problems [7].

LU/LCC has negative consequences on both the quality of the environment and life [8]. Noted that the environmental consequences of LU/LCC are as large as that of climate change. LU/LCC can affect food security, biodiversity, biogeochemical cycles, soil fertility, hydrological cycles, energy balance, land productivity, and the sustainability of environmental service provision it also contributes to global warming [2].

Forest is one of the most essential kinds of resources that human beings and other animals depend on. It adjusts environmental and ecological changes in which soil, water climate and rainfall are in good existence in a sustainable situation. The value of forest resources to the world's human population is becoming increasingly evident. The forest has been either modified or converted. If modified, once dense stands of closed forests have been replaced by more open stands of secondary species that yet further changed into savanna of open grasslands and the whole process frequently being a prerequisite to clearing for agricultural activities [9].

Assessment of the spatial and temporal distribution of LU/LC is an essential pre-requisite for land resources planning, management, and monitoring programs have also noted precise information on LU/LCC. Its driving forces are essential to understand what type of changes have occurred and are expected in the future. Moreover, analysis of LU/LCC and its drivers provides overall information for monitoring biodiversity loss and natural disasters (e.g. drought, floods, wildfires),and for identifying areas susceptible with severe land degradation (e.g. deforestation, overgrazing, diversion of water resources, etc.) [10].

GIS and remote sensing technologies have made possible to assess and analyze LU/LCC in less time, at low cost and with better accuracy [11]. Availability of remotely sensed data in various spatial and temporal resolutions made mapping and assessing LU/LCC possible [12]. On the other hand, GIS has tools for collecting, storing, analyzing, and visualization of the outcome of analysis[13].

Therefore, in this research study emphasis was given to assess the forest cover change and driving factor rate of deforestation in Ethiopia case of Adaba-Dodola district forest area and mapping the land use land cover change by using the integrated techniques of remote sensing and GIS technology.

2. MATERIALS AND METHODS

2.1 Study area

Adaba-Dodola district is located in Southeastern part of Ethiopia, found in Oromia regional state, West Arsi Zone, which is approximately at a distance of 340 km far away from the capital city of Ethiopia, Addis Ababa. The study site is situated between 6^0 5^0- 7^0 0' north latitude and 39^0 07- $39^0$22' east longitude. It shares bounder line with Kofale and Gadaba Asasa to the north, kokosa to the west, Bale Zone to the East, and Nansabo district to the south. Most parts of the district have elevations of ranging from with an attitude between 2400-3753 m above sea level.

The agro climate zone of the study area ranges from dega to wurch (cool and humid) which are characteristics of most of the Ethiopian high lands. The rainfall distribution is bimodal having two rainy seasons per year. This great variation of temperature provides wide opportunities for the production of different types of crops range from warm to cool thermal zone. However, there is a slight variation in temperature from month to month. October to May is the hottest months while June to September is the cold and Mean Annual Rainfall for most of the areas, the rainy season starts in March and extends to November with the highest concentration in June, July and August. The dry season lasts from November to February, followed by the short rainy season during the months of March and April. From the weather records of 1994-2004, the average rainfall of the study area is 733 mm [14]. The temperature ranges from 7-24°C. and the average elevation ranges from 2,400 to 3,800 meter above sea level.

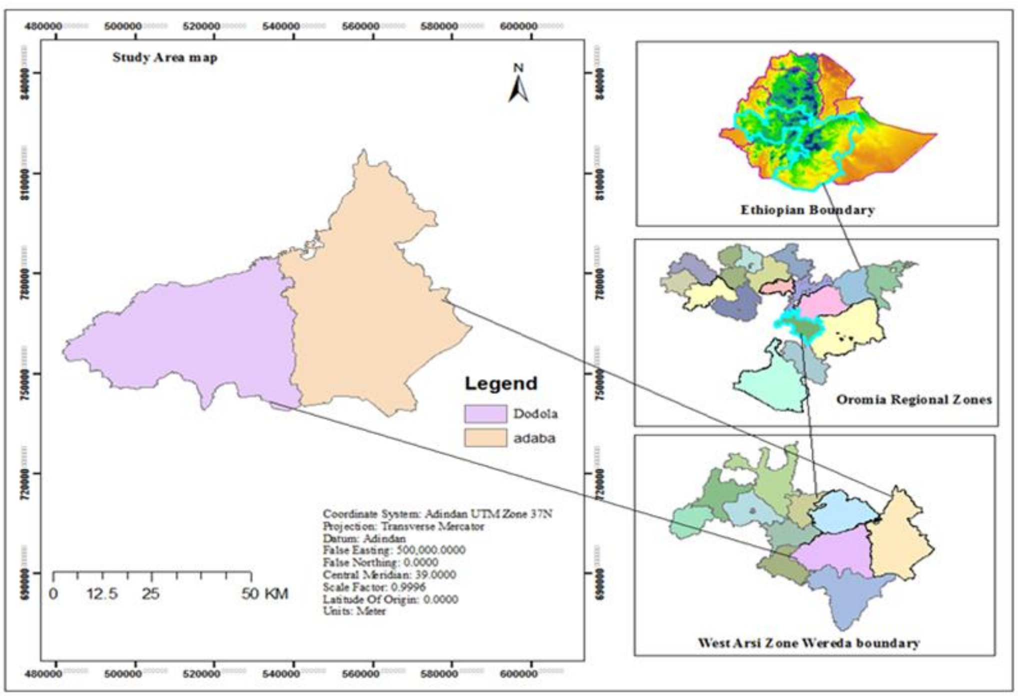

Fig.1. Location map of the study area.

2.2. Sources and Types of Data

To meet the objectives of this research different kinds of data were collected from both primary and secondary data sources. This study integrates both remote sensing and geographic information systems techniques based on a semi-structured questionnaire and interviews with village elders. To investigate forest LULC change in two study areas and to improve the accuracy gaps in information got from remotely-sensed images, local people are frequently used as a valuable complement. Besides filling the gap in information, interviews with local people could also clarify ambiguities in interpreting remotely sensed images; justify the data collected, and explain the underlying causes of the phenomena observed.

The procedure followed in this study was presented using the flow chart (**Fig.2**). It shows the steps followed beginning from the acquisition and classification of the multi-temporal satellite image of the study area to the extraction of the required information both secondary and primary data to answer the research questions.

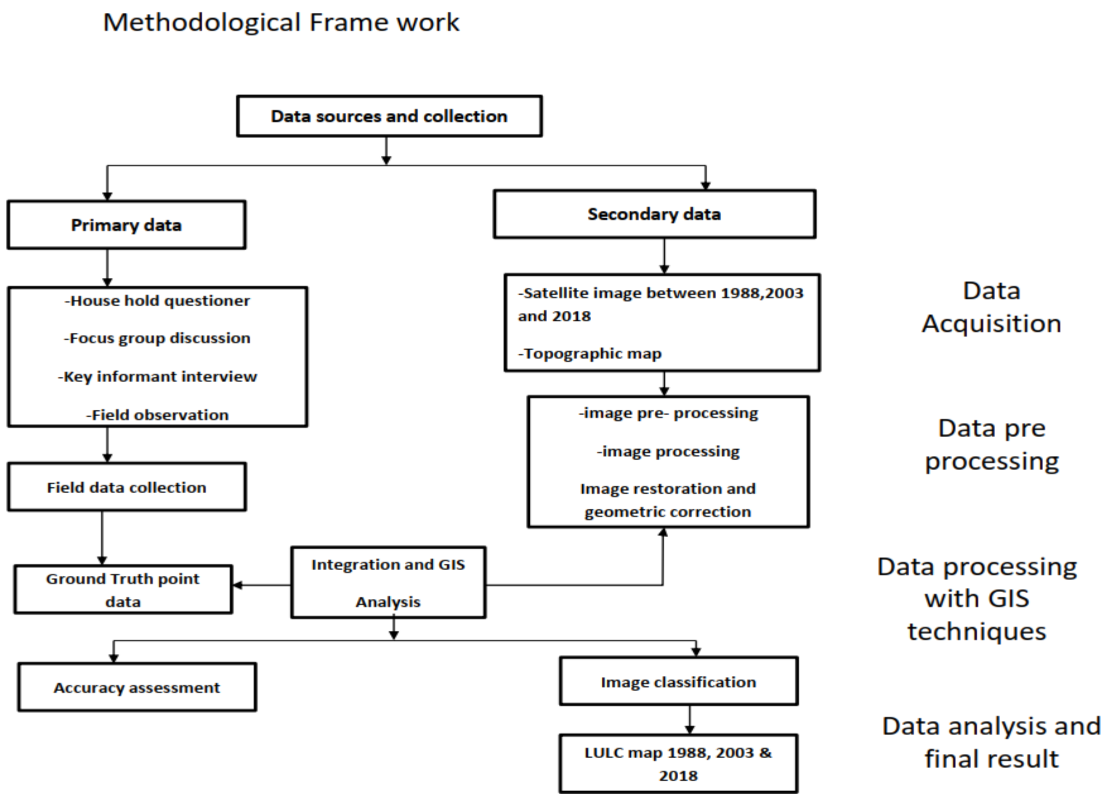

Fig.2. Conceptual framework of the study area.

2.3. Data Acquisition

2.3.1. Image selection and acquisition

Thematic Mapper (TM) and Landsat-7 Enhanced Thematic Mapper (ETM+) images were obtained for the years 1988, 2003 and 2018 (**Table 1**), a period of 30 years which provide ample time to monitor LULC change. An effort was made to acquire cloud-free image scenes. The large area of the entire Landsat satellite scenes gained for difference years, it was necessary to clip out only the study district of interest, which covered 379755 ha, before any analysis was conducted. The images were processed using ERDAS Imagine 9.2, and ArcGIS 10.2 software. Image enhancements used on different year images were histogram equalization for stretching and false-colour composite for display. Supervised classification, using the maximum likelihood algorithm, was adopted. Training data for the supervised classification were established from the author's knowledge of the area, and with the help of other supporting data sources, such as Google earth and interviews with elderly people. The field survey, conducted in September 2019 at a season comparable with that when the satellite images were acquired, also assisted in locating reliable training sites for the supervised classification.

Table 1. Remotely sensed data used in the analysis of land use/cover change.

Study area	Satellite Sensor	Path/Row	Acquisition data (M/D/Yr)	Spatial resolution
Adaba	Landsat7 ETM+	P168/55	1988/11/10	30
			2003/02/05	30
	Landsat8 OLI TIRS		2018/01/29	15
Dodola	Landsat 7 ETM+	P167/55	1988/11/10	30
			2003/11/28	30
	Landsat8 OLI TIRS		2018/03/11	15

Source: Satellite image data

3. Data Analysis

3.1. Image pre-processing and atmospheric correction of scenes

The Landsat images were downloaded from the U.S. Geological Survey (USGS) Earth Explorer website. The images were already geo-referenced to rectify for alignment, and coregistered to the Universal Transverse Mercator (UTM) projection system (zone: 37N, datum: WGS-84) avoiding the need for geo-rectification, which would have employed ground control points (GCPs), paying attention to acquire the least root mean square error (RMSE) in pixels. The image layers were imported and layer stacked to form multispectral images. These steps were carried out in ERDAS Imagine 2014.

Remotely sensed satellite data are affected by artifacts, such as haze resulting from water vapor and aerosol particles present in the atmosphere which influence the sensor signal.
For land cover change detection using multi-date satellite-derived images, proper atmospheric correction is necessary because differences in the atmosphere for the two dates can present a false indication of change or mask areas of real change [15]. Impacts of atmospheric correction on image classification are evaluated. This needed atmospheric correction of the scenes to reduce significant errors in image classification. Besides, the use of multi-temporal images requires atmospheric correction of scenes earlier classification processes.

3. 2. Image classification

A supervised land cover classification was used to classify the images into six main land cover/land use categories of open forest, dense forest, agricultural land, grass, settlement or built-up area, and water (**Table 2**). The supervised classification allows the user to define areas of interest (AOIs) that identify and recognize features on the image. The AOI's (training samples) were collected for the various land cover/use categories, based on a) prior knowledge of the area, and b) uniformity in appearance using ArcGIS 10.2. The AOI's were used to create a signature file for each Landsat scene. The signatures were evaluated using histograms, band by band scatter plots and a separability analysis to obtain the expected error, the covariance between bands in the classification for various feature combinations [16].

Table 2. Land use classes considered in image classification and change detection

Land cover/land use Classes	Description
Dense forest	This class represents the evergreen forest and mountain forests. The general tree height was from 18 – 40 m and the crown coverage is over 60% (IFMP, 1999).

Open forest	This class corresponds to the forest, which was disturbed by human activities. It is composed predominantly of regeneration forest from the past disturbance such as logging. The general height in this class range 2m to 25m tall. The crown coverage was generally below 60 % (IFMP, 1999).
Grassland/Rangeland	Both communal and\or private grazing lands that are used for livestock grazing. The land is covered by small grasses, grass-like plants and herbaceous species. It also includes land covered with a mixture of small grasses, grass-like plants and shrubs less than 2m and it is used for grazing
Settlement/Builtup area	All residential, commercial and industrial area, transportation infrastructure, settlements (may include greenhouse plastic covers).
Agriculture	Made to include areas allotted to rain-fed cereal crops Cultivated large-scale farms, fallow, cultivated crops such as wheat, maize, beans, vegetables, barley, and teff etc. Crop cultivation both annuals and perennials, mostly in subsistence farming
Water	Permanent open water, lakes, reservoirs, streams, dams, bays and estuaries.

3.3. Accuracy assessment

Accuracy assessment is important that it tells us to what extent the truth on the ground is represented on the corresponding classified image. Accuracy assessment analysis was carried out to validate the classification results. In this study, an error matrix was generated based on the year 2018 land use/land cover classification and 60 ground truth point data were made the study district see **Table 3**. The accuracy is essentially a measure of how many ground truth pixels were classified correctly.

These tables produce many statistical measures of thematic accuracy including overall classification accuracy, percentage and the kappa coefficient, an index that estimates the influence of chance [17]. Errors of commission and omission can also be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed, while the producer's accuracy represents the percentage of a given class that is correctly identified on the map. One of the problems with the confusion matrix and the kappa coefficient is that it does not provide a spatial distribution of the errors [18]. The quality and sufficiency of reference data are important if reliable accuracy assessment is required. A reference data that is not verified thoroughly should not be expected to set accuracy standard. The insufficient number of verified data also affects the quality of the assessment [17].

Table 3. Confusion matrix of the year 2018 Land cover/Land Use Supervised Classification

	Grassland	Water	Dense forest	Settlement	Open forest	Agriculture
Grass land	90	0	0	0	0	0
Water	0	100	0	0	0	0
Dense forest	10	0	90	0	0	0
Settelement	0	0	10	100	0	10
Open forest	0	0	0	0	100	0
Agriculture	0	0	0	0	0	90
Total	100	100	100	100	100	100

Class	Product Accuracy (Percent)	User Accuracy (Percent)

Grassland	90	100
Water	100	100
Dense forest	90	90
Settelement	100	83.33
Open forest	100	100
Agriculture	90	100

Overall Accuracy = (57/60) 95%

Kappa Coefficient =94.05

Overall accuracy of 95% was achieved with a Kappa coefficient of 0.9405. The Kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. This implies that the Kappa value of 0.9405 represents a probable 94% better accuracy than if the classification resulted from a random assignment.

3.4. NDVI Image Comparison and Change Detection Result

As indicated earlier, the spectral band ratio is one of the most common mathematical operations applied to multi-spectral data. Ratio images were calculated as the divisions of digital number values in one spectral band by the corresponding pixel value in another band. Based on the reflectance pattern of vegetation, different models of vegetation indices were developed to explain the healthiness, vegetation cover and biomass condition of vegetation. Various mathematical combinations of the Landsat channel 3(Red band) and channel 4(NIR band) data were found to be sensitive indicators of the presence and condition of green vegetation. Among these, NDVI is the most commonly used index for forest vegetation biomass monitoring. The absolute value of NDVI for vegetation change analysis is between 0 and 1. NDVI analysis was employed to get an overview of the vegetation biomass change based on 1988(**Fig.3 A**), 2003(**Fig.3 B**) and 2018 (**Fig.3 C**) satellite image. The NDVI empirical analysis is computed using equation (1).

$$\boldsymbol{NDVI} = \frac{\textbf{Near infrared} - \textbf{Visible red}}{\textbf{Visible red} + \textbf{Near infra red}}. \quad \textbf{.........} \text{ Equation (1)}$$

Where, NIR=Image of Near-Infra Red,

As to vegetation conditions, NDVI values vary from 0 to +1. Healthy vegetation yields have high positive NDVI values because of their relatively high reflectance in NIR and low in the visible wavelength. After conducting NDVI analysis, the mean and standard deviations values were summarized using ERDAS IMAGINE 9.1 software to evaluate the trends of vegetation cover change condition of the area. Then, the mean and standard deviation result is obtained within the ranges of 0 and 1 and the following the statistical values of each of the images were presented in **table 4**.

Table 4: Statistics for NDVI analysis

Type	Year		
	1988	2003	2018
Minimum	-0.6667	-0.7067	-0.14474
Maximum	0.74699	0.70149	0.999872
Mean	0.1954	-3.8221	-0.029
Median	0.0374	0.0053	0.4253

Standard Deviation	0.195	0.185	7.998

Source: Satellite Image Interpretations

As indicated in **table 4**, the standard deviation of the 1988 image is 0.195, which is a greater value comparing with the value of the 2003 NDVI image has a value of 0.185 and 7.998 in 2018.

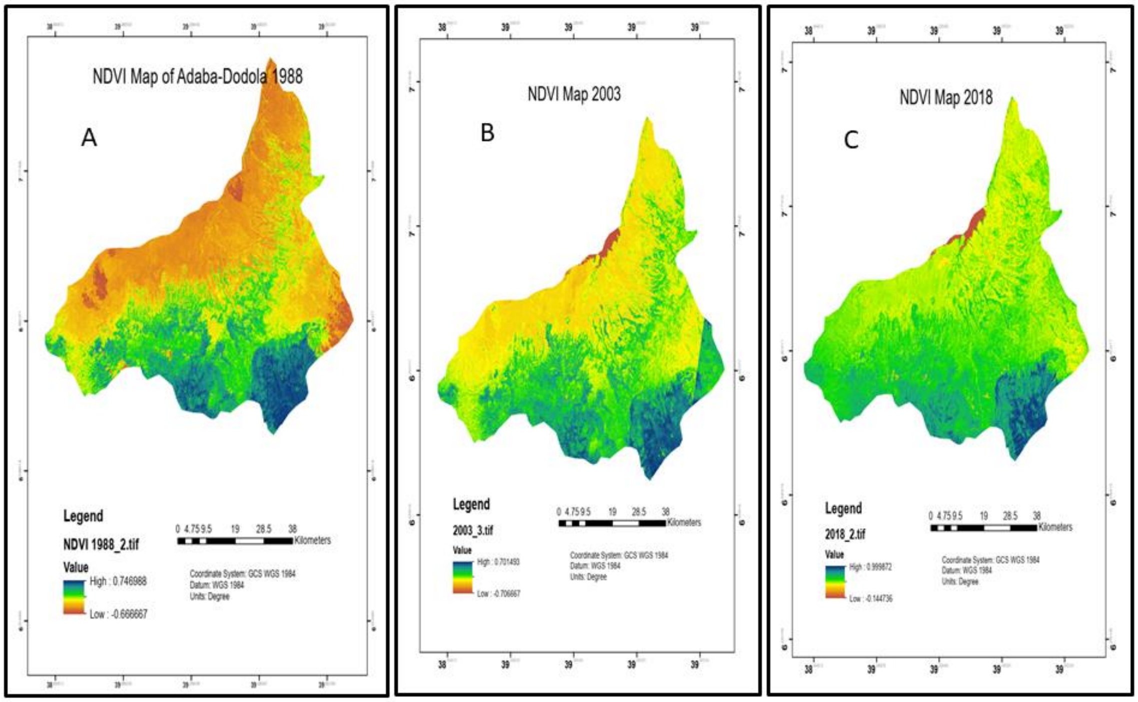

Fig. 3. NDVI Map of Adaba-Dodola District, 1988 A ,2003 B , and 2018 C
Source: 1988, 2003, and 2018 Image Interpretation

3.5. Characteristics of LU/LC units

The distribution of land cover/land use units of the study area is categorized into six classes, the major LU/LC types were identified by using the field data and satellite images of Landsat TM, 1988, 2003, and 2018. These were the dense forest, open forest, grassland, settlement/built-up area, agriculture, and water body (**Table 2**). The water body was added as a new LU/LC type in the Landsat images of TM 2003, and OLI TIRS 2018 to the presence of electric power dam in these images. Rivers, streams, and springs were not included in the classification. This is due to resolution problem of the image (30 m). In the classification, the forest was made to include human-made plantation forest and natural forest. This both natural forest and plantation forests categorized under dense forest and open forest based on NDVI value and field verification. The areal extent of each land covers land use types with a respective area in (ha) and the percentage is presented in **Table 5**.

Table 5. Summary Statistics of Land cover/ Land Use units of Adaba-Dodola District; 1988, 2003 and 2018

number	class name	1988		2003		2018	
		Area ha	%	Area ha	%	Area ha	%
1	Settlement	2347	0.61803	23452	6.175561	27476	7.235191

2	Grass land	34539	9.095074	26353	6.939474	33650	8.860976
3	Open forest	62004	16.32737	92297	24.30435	139008	36.60465
4	Dense forest	174429	45.93198	109830	28.92128	61468	16.18623
5	Agricultural land	106436	28.02754	125113	32.94572	115298	30.36115
6	Water	0	0	2710	0.713618	2855	0.751801
	total	379755	100	379755	100	379755	100

Source: Computed from Satellite Image Interpretation

4. Results

4.1. Land cover change in 1988,2003 and 2018.

The resulting maps indicate broad variations in LULC that occurred during the 30 years of study for Adaba-Dodola. **Fig.4** shows the land cover maps for 1988, 2003, and 2018 for the study area. The overall accuracies based on 2018 LULC maps were above 95%, and Kappa statistics were 0.94 or 94.05% indicating a strong to better accuracy acceptable agreement between the classification map and the Google Earth reference information[19].

From the 1988 landcover and land use map interpretation and classification, the areal coverage of dense forest was accounted for 174429 ha (45.9%) from the total study area. The open forest land and grasslands were occupied about 62004 ha (16.3%) and 34539 ha (9.1%), respectively. Besides, agricultural land 106436 ha (28%) and settlement 2347 ha (0.62%) was accounted for the total coverage of the study area.

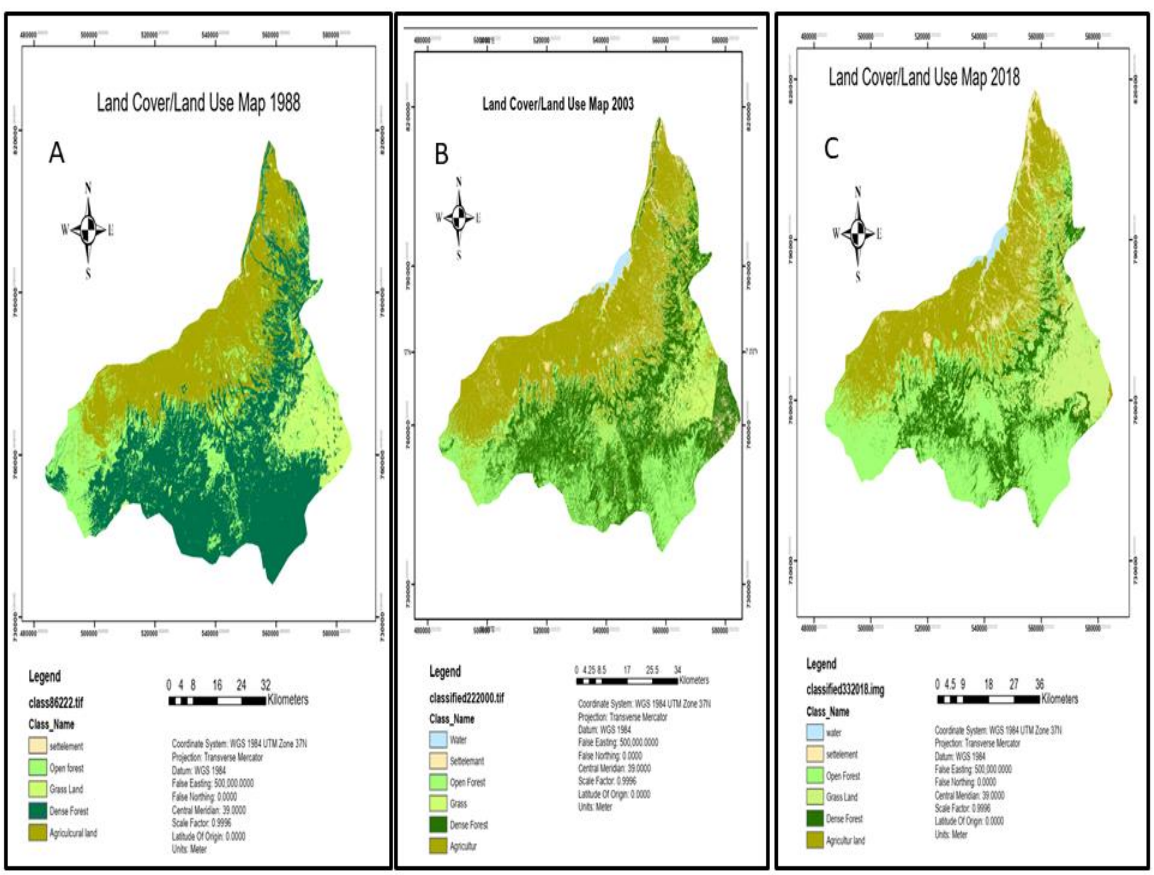

Fig.4. Land cover/land use map of Adaba –Dodola District,1988 A, 2003B & 2018 C.

Source : 1988,2003 & 2018 Satellite Image Interpretation.

From the 2003 land cover and land use map interpretation and classification, the areal coverage of dense forest was accounted for 109830 ha (28.9%) from the total study area. The open forest land, grassland and water body were occupied about 92297 ha (24.3%), 26353 ha (6.94%) and 2710 ha (0.71%), respectively. Besides agricultural land 125113 ha (32.95%) and settlement 23452 ha (6.18%) was accounted from the total coverage of the study area.

In 2018, from the total land coverage, agriculture land was accounted for about 115298 ha (30%). Dense forest and open forest take the share of 61468 ha (16%) and 139008 ha (36.6%), respectively. Waterbody 2855 ha (0.75%) covered from the total of the study area. The remaining area was covered with settlement and grassland 27476 ha (7.2%) and 33650 ha (8.86%).

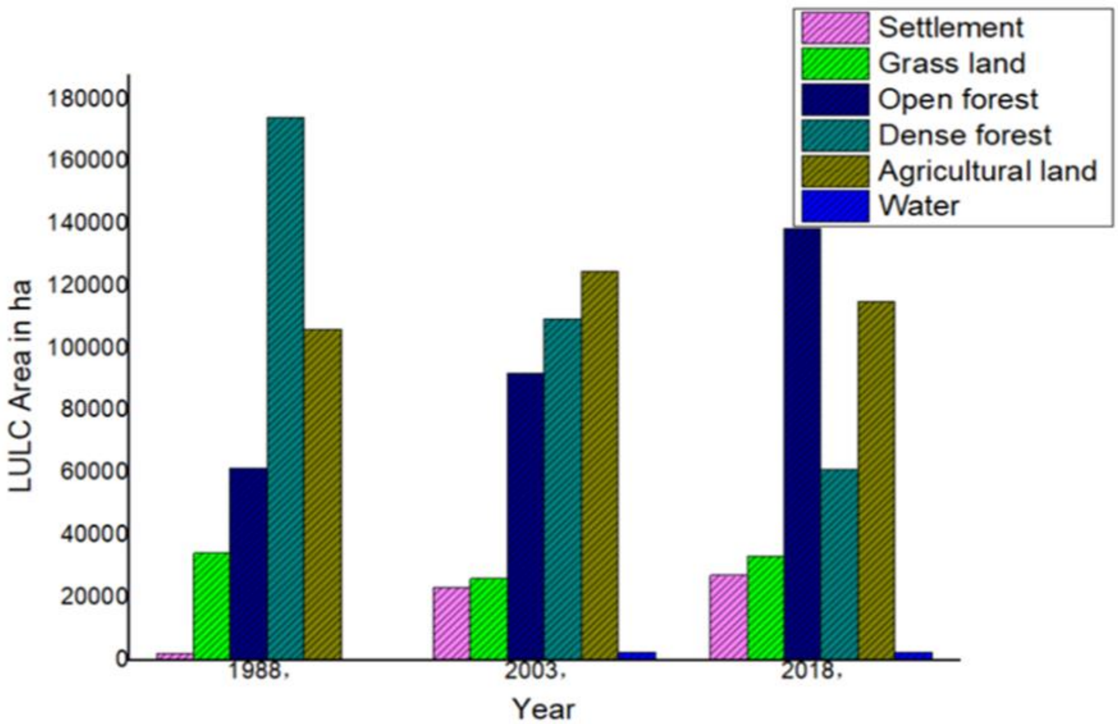

Fig.5. Land cover/land use of Adaba –Dodola District, 1988 , 2003 & 2018

4.2. Area extent and rate of forest cover change

Assessment of forest cover change was done using remote sensing and GIS techniques with the integration of field survey. In this study, three Landsat satellite images (see table 1) were used to monitor the areal extent and rate of forest cover change within time sequence. During the analysis stage, digital image interpretation of forest cover area for each year was performed. The total area of the forest cover in terms of ha and its a percentage from each date of satellite interpretations were computed and summarized. In order to determine areas of the forest to be subjected to different change extract the area covered with both forest type (dense forest and open forest) therefore requires the extraction of polygons representing the forest areas. **Fig. 6** and **table 6** revealed that the pattern of forest cover changes between 1988, 2003, and 2018.

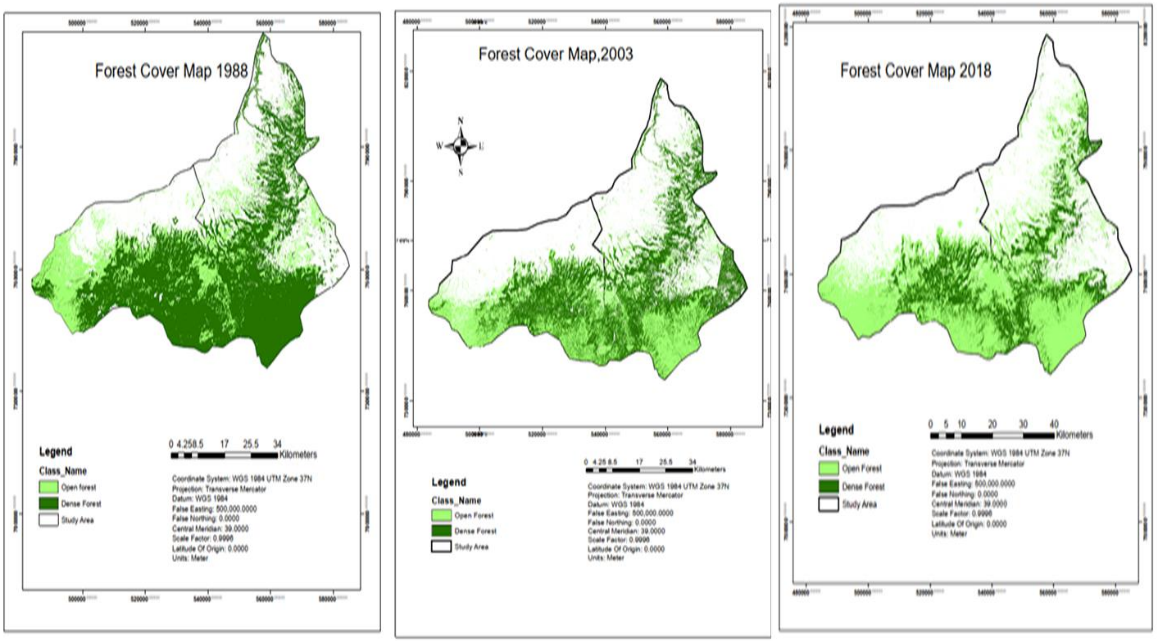

Fig.6. Forest Cover Map of Adaba –Dodola District, 1988,2003 and 2018
Source: Derived from 1988,2003 and 2018 Land Cover/Land use Map

From this result, about 236433 ha of the district was covered with forest resource in the year 1988. Meanwhile, the forest cover land of the district was accounted for 202127 ha and 200476 ha in the year 2003 and 2018, respectively. The percentage share of each year forest cover value and with its diminishing trend is presented in **Fig. 7**.

Table 6； Total Forest Covers Land Area of Adaba- Dodola District; 1988, 2003 and 2018。

Year	Forest Cover Types	Forest Cover unit from the total area (in ha)	Forest Cover In %
1988	Open forest	62004	16.32737
	Dense forest	174429	45.93198
	total	236433	62.25935
2003	Open forest	92297	24.30435
	Dense forest	109830	28.92128
	total	202127	53.22563
2018	Open forest	139008	36.60465
	Dense forest	61468	16.18623
	total	200476	52.79088

Source: Computed from table 5.

Distribution and Forest Cover Change

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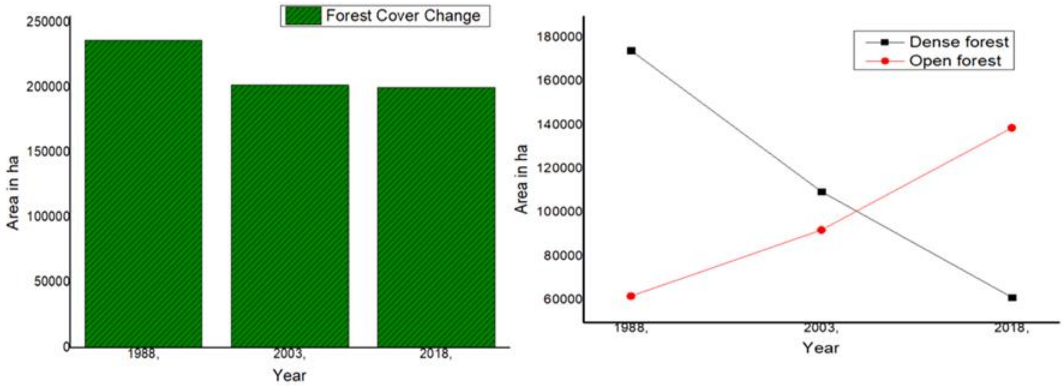

Fig.7. Distribution of forest cover with percentage and area in hacker value 1988,2003 &2018.
Source: Computed from table 6.

In the year 1988, 45.9% & 16.3% dense and open forest of the district was covered with forest resources while from the total area of the district about 28.9% & 24.3% was covered with forest resources in 2003. In the meantime, this figure turned down into 16.2 & 36.6 % in the year 2018. Based on this data, the rate of forest cover change also computed and its results presented in **Table 7**.

Table7. : Trends and Rates of Forest cover change In Adaba-Dodola District

cover class	year			Rate of Change		
	1988	2003	2018	1988-2003	2003-2018	1988-2018
Open forest	62004	92297	139008	2019.5	3114.1	2566.8
Dense forest	174429	109830	61468	-4306.6	-3224.13	-3765.37
Total Forest Cover & loss in ha	236433	202127	200476	-2287.1	-110.1	-1198.57

Source: Computed From Table 6

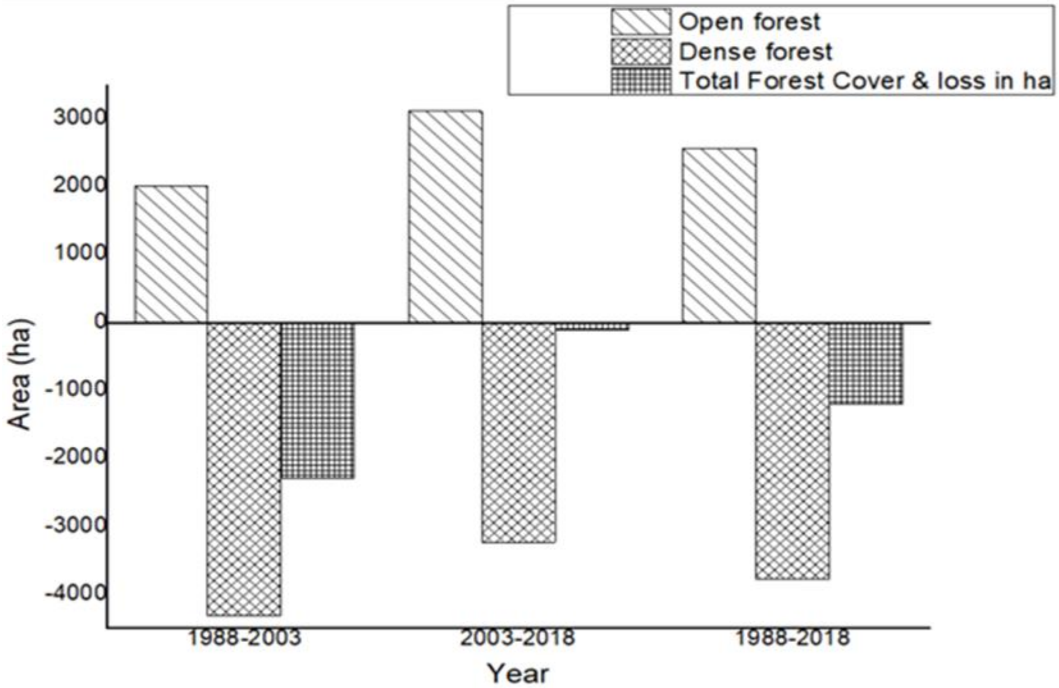

Fig.8. Rate of forest cover change
Source: Computed from Table 7

The computed result (Table7. above) shows that the average rate of forest cover change from the year 1988 to 2003 is -2287.1 ha per year (202127 ha – 236433 ha / 15 years) and from the year 2003 to 2018, it was -110.1 ha annually (200476 - 202127 ha/ 15 years). the rate of forest cover change was lower in the year 2003-2018 than the rate in the year 1988-2003. Because from the year 2002 there was establishment of integrated forest management project in the area in local language WAJIB (Waldaa Jiraatoota Bosona) approach which means forest dweller association. Besides, considering the annual rate of forest cover change between 1988 and 2018, the computed result is -1198.57 ha per year (200476 – 236433 ha /30 year).

4.3. Detection of land cover change matrix between 1988 and 2003.

Giving special consideration to dense forest cover the major cover changes observed during this period shows that 79789.53 ha of forest cover were converted to other classes. From dense forest to grassland 5728.309 ha, dense forest to settlement it was 6713.272 ha, dense forest to open forest 63430.88 ha was converted and 3917.078 ha of dense forest was shifted to agriculture land. As indicated in **Table 8**, overall before the establishment of WAJIB institution forest cover loss was 79789.53 ha, gain 15259.27 ha and the net change was negative (64530.3 ha). During this period 94571.26 ha of dense forest land was unchanged (constant) to other classes.

Table 8: Land-use /land cover change matrix between 1988 and 2003

Land Class		Land Class 1988 Initial state					Class total
		Grass Land	Dense Forest	Settlement	Open Forest	Agriculture	
Class 2003 final	Grass Land	14988.52	10533.16	3253.624	2221.91	3443.381	34440.6
	Dense Forest	5728.309	94571.26	6713.272	63430.88	3917.078	174360.8

Settlement	41.11101	146.9231	858.646	82.86088	1121.317	2250.858
Open Forest	4499.262	3909.563	2741.476	24488.11	26285.93	61924.34
Agriculture	1095.439	669.6292	9884.84	2073.074	90345.5	104068.5
Class total	26352.64	109830.5	23451.86	92296.83	125113.2	377045.1
Gain	11364.12	15259.27	22593.21	67808.72	34767.7	
Loss	19452.07	79789.53	1392.212	37436.23	13722.98	
Net	-8087.95	-64530.3	21201	30372.49	21044.72	

4.4.Detection of land cover change matrix between 2003 and 2018

During this period **58521.611 ha** of dense forest land was converted to other classes. Specifically, when we see the changes, 10716.055 ha was converted from dense forest to grassland, 7.367 ha to water, 4844.615 ha to settlement and 40739.815 ha was to open forest land. As indicated in **Table 9**, after the establishment of WAJIB institution agriculture land cover loss was 27059.632 ha, which is greater than it does before the local institution due to control expansion of illegal farmland. The gain from other classes was only 10205.56 ha and hence, the net change was **negative** (48316.05 ha). During this period 51205.045 ha of dense forest land was unchanged to other classes, which are minimal compared to the time before the local institution was established in the area and the areal coverage of agriculture was reduced.

Table 9: Land-use /land cover change matrix between 2003 and 2018

Land Class		Land Class 2003 Initial state						
		Grass Land	**Water**	**Dense Forest**	**Settlement**	**Open Forest**	**Agriculture**	**Class total**
Land Class 2018 final state	Grass Land	16855.74	0.3249	2609.72	759.7463	4842.217	1305.447	26373.2
	Water	0	2593.247	0.022394	10.03156	0.143294	102.4635	2705.908
	Dense Forest	10716.05	7.367137	51262.44	4844.616	40739.82	2213.758	109784.1
	Settlement	1614.347	203.7095	487.6751	6824.497	4994.964	9326.083	23451.28
	Open Forest	3108.894	0.001072	6875.583	3255.382	74790.83	4256.49	92287.18
	Agriculture	1354.96	50.3505	232.56	11781.73	13640.03	98093.76	125153.4
	Class total	33650	2855	61468	27476	139008	115298	379755
	Gain	16794.26	261.7531	10205.56	20651.5	64217.17	17204.24	
	Loss	9517.455	112.6608	58521.61	16626.78	17496.35	27059.63	
	Net	7276.8	149.0923	-48316.1	4024.724	46720.82	-9855.39	0

5. Discussion and Conclusions.

This study offers an assessment of forest LU/LCC and its driving factors in Adaba-Dodola District in Ethiopia. The district is composed of six major LU/LCC types: dense forest, open forest, grasslands, agriculture, settlement, and water body. The quantitative evidence of land cover dynamics presented was delivered by repeated satellite images coupled with GIS analyses and field survey data analyses.

From the analyzed results, the magnitude of land-use/land-cover in general and forest cover change in particular was observed between the year 1988 and 2018 in the study area. Particularly, expansion of settlement, agriculture, and grassland decline of dense forest land were observed.

In relation to this, currently, the overall condition of the forest cover land of the study area is strongly disturbed. Besides, the areal extent of forest cover is reduced from time to time. The findings indicated that the total area of the forest land (both dense and open forest) cover was about 236,433 ha in 1988. But, the cover area declined to 200,476 ha in the year 2018. Moreover, for the annual rate of forest cover change between 1988 and 2018, the computed result indicated a loss of 1198.57 ha forest land into other land use. Yet the loss rate of forest cover was 2287 ha during 1988 to 2003, but reduced to 110 ha between 2003 to 2018, due to the practice of WAJIB project. The major factors for the forest land cover change in the study area are agricultural land & settlement expansion, firewood and charcoal production, demand for construction materials and income growth. Not only led to deforestation these factors also aggravated land degradation, soil erosion and biodiversity loss in the area.

Besides the land use/land cover change detection employed GIS and Remote sensing techniques, the results demonstrate that after the establishment of WAJIB institution, the areal extent of forest cover had declined and changed to the other land use land cover. Hence, this type of data was very useful for the concerned bodies in protecting the remaining forest resources from distraction.

Overall, it is evident that the forest cover land of Adaba-Dodola has declined despite the rate was alleviated in the past three decades. In order to protect the forest resources from further depletion and to use these precious resources on a sustainable basis, the following recommendations are suggested.

1) To increase the forest boundary awareness, additional forest boundary maps should be disseminated to the community. It will help to create a greater sense of forest resource ownership & lessen disputes resulting from confusion over the boundary of forest between communities.

2) To raise the carrying capacity on modern agriculture extension services.

3) To curb the woodcutting for household energy, improved stove for rural residents should be devised.

4) To overcome the problem of soil erosion, and water conservation methods should be studied and implement.

5) The family planning awareness creation campaigns with adequate health services should be introduced.

6) To protect the forest resources from further destruction.

7) To control illegal cutting trees for fuel wood and increase awareness of the ecological value of the forests as well as the consequences of deforestation.

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Abbreviations

GIS- Geographical Information system

RS- remote sensing

NDVI – normalized different vegetation index

WAJIB (in local language Waldaa Jiraatoota Bosona) which means forest dweller association

KEBELE- A lower administrative structure of the country

LULC- Land use land cove

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