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Full Length Research Paper

Land Use and Land Cover Changes and Associated Driving Forces in North Western Lowlands of Ethiopia

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Abstract

Woodlands in Ethiopia are under heavy pressure and shrinking overtime. Despite the woodland's economic and ecological importance's, little attention has been given to monitor the condition of the resources through time. The aim of this study is to assess the status of western dry woodlands of Ethiopia by analyzing land use and land cover (LULC) dynamics and recommend their future sustainable management and development in view of their multi-functions, climate change mitigation potentials as well as local livelihood improvement. Remote sensing (RS) and Geographic Positioning System (GIS) were used to assess the LULC dynamics in three regional states (Amhara, Tigray, and Benshangul-Gumz). Three study sites: Metema, Kafta-Humera and Sherkole were selected, respectively. In all study sites the classes of agricultural land and bare land have expanded at an average rate of 2322.9 and 726.6 ha/year, respectively. On the other hand, the woodland cover in the three districts was decreasing at an average rate of 2833.8 ha/year in the past 25 years (1985-2010). The woodland cover was transformed mainly to agriculture at an average rate of 2057.9 ha/year.

Keywords: Agricultural expansion, deforestation, land use and land cover, resettlement, woodland.

INTRODUCTION

In Ethiopia, nearly > 65% of the country's land mass is located in dry land areas and they are associated with tropical dry forest (NCSS, 1993). Woodland's of Combretum-Terminalia and Acacia-Commiphora are the two dominant vegetation types that cover large parts of the dry land areas (Eshete *et al*., 2011). They possess important diverse tree species, e.g., *Boswellia papyrifera,* that provide the widely known and traded frankincense (Eshete *et al*., 2011; Eshete *et al*., 2012). Moreover, woodlands provide poles, timber, fodder, energy, nectar and gum, which are useful for subsistence, income generation, traditional medicine, and religious ritual for the local households (Lemenih and Teketay, 2003). In addition to subsistence and economic values, they could play an important role in environmental protection and global carbon balance (as carbon sources and sinks), and they have a potential to combat global climate change (FAO, 2005; Lal, 2005; O'connor, 2008; Sheikh *et al*., 2009) if they are well managed sustainably.

Ethiopian woodlands' are under heavy pressure and shrinking overtime for extracting fuel and construction wood, for expansion of cash crops (e.g., Sesame). Additionally, population growth and government induced resettlement programs aggravate deforestation and subsequently resulted serious environmental degradation in the highlands of the country and response to recurrent droughts (Berhan, 2005; Feoli, 2002; Eshete *et al*., 2012; Garedew *et al*., 2009; Gebresamuel 2010; Lemenih and Kassa, 2011, Kassa *et al.,* 2014; Rahmato, 2003; Tsegaye *et al*., 2010) This led to increase societal vulnerability to recurrent droughts.

Despite the woodland's potential, little attention has been given to monitoring of these valuable resources in Ethiopia (Lemenih *et al.* 2007; Tadesse *et al.* 2007). It is important to assess the status of Western dry woodlands of Ethiopia to analyze the land use and land cover changes and to recommend their future sustainable management and development in view of their multi-functions, climate change mitigation, local livelihood improvement through carbon trading and gum and resin production.

Remote sensing (RS) and Geographic Positioning System (GIS) provides a reliable source of data for assessing and monitoring spatial and temporal land use and land cover changes. A combined use of RS and GIS technology can be invaluable to address a wide variety of resource management problems (Tekle and Hedlund, 2000). Land use and land cover maps can be a powerful tool to compare their changes of an area over time and with them possible to analyze a large area of land in short period of time (Billah and Rahman, 2004).

The study provides insights into the rate of woodland resource changes to be a base line study for associated changes in carbon stocks, potential income generation from carbon trading and Gum and Resin marketing, which would contribute in developing sustainable dry land natural resources management towards building up climate resilient livelihoods in dry land areas of Ethiopia.

The objective of this study is to assess dry land forest vegetation cover, to quantify spatial and temporal trends of land use and land cover changes in the three study areas; and ultimately to draw recommendations on sustainable woodland management and development.

MATERIAL AND METHODS

Description of study areas

Three study sites; Kafta-Humera in Tigray Regional State,, Lemlem Terara in Amhara Regional State and Gemed/Sherkole in Benshangul-Gumz regional state were selected to provide instights in to land use land cover changes in the Western lowlands of Ethiopia. The sites selected for this study are gum and resin tapping concession areas owned by the Natural Gum Processing and Marketing Enterprise.

a) Kafta Humera

This district is located in Tigray Regional State, north-western Ethiopia at 36^0 27' 4.7'' to 37^0 33' 7.1'' E and 13^0 39' 46.5'' to 14^0 26' 34.9''N with the altitude range of 560-1849m a.s.l. The district is located in semi-arid agro-climatic zone and covers an area of 632,878 ha. The geological classifications of the district are mainly dominated by early tertiary volcanic and Pre-Cambrian rocks (Mohr, 1966). The dominant soil types in the study area are Chromic Eutric and Calcic Combisols; Chromic and Orthic Luvisols and Chromic and Pellic Vertisols (EMA, 1988). The vegetation communities in the district include Acacia-Commiphora, Combretum-Terminalia and dry evergreen woodlands (Eshete *et al*., 2011, Sebsebe and Friitz, 2011). The total rainfall ranges from 400-650 mm. The mean maximum temperature varied between 33^0C in April and 41.7^0C in May, while the mean minimum temperature is between 17.5^0C in August and 22.2^0C in July. The rainy season of the study area is from June to September. The remaining 8-9 months are dry and hot (Kafta Humera District Livelihood Report, 2011).

The land use system was characterized by mixed farming system dominated by open crop cultivation; and this included cereals (31.24%), pulses (5.94%), oilseeds (60.87%) and vegetables (1.95%) (CSA, 2007). The economy of the district is mainly centered on the production of sesame, but after 1996 it was replaced by cotton as the primary cash crop. Over 400 large scale investors cultivate an average of 600 hectares of sesame, while local farmers cultivate up to 12 hectares/head. In the district, investors cultivate 58% of the cultivated land while local farmers use the remaining 42%.

Population in the district has almost doubled from 48,690 in 1994 to 92,144 in 2007 (CSA, 1994, 2007). The population density is 14.56/km^2, which is less than the national average 77.72/km^2. A total of 23,449 households were counted in this district and the average household size is estimated to be 3.93 persons.

b) Metema

Metema district is located in the North western Ethiopia (35^0 45' 21.34'' to 36^0 45' 31.31'' E and 12^0 17' 33.63'' to 13^0 5' 52.52'' N) in the Amhara regional state The total annual rainfall of the district ranges from 700-900 mm with minimum annual temperature between 22^0C and 28^0C and mean maximum annual temperature between 35 and 45^0C. The agroecological zone of the district is classified as semi-arid and the elevation gradient ranges between 550 and 1600 meters a.s.l. (MDOA, 2011) (Metema District Office of Agriculture).

The major land use and land cover types observed in the district were arable land (42.21%), pasture (7%), forest and shrub land (41.11%) and the remaining 9.68% is considered as a degraded or other land. Teff, corn, sorghum, cotton and sesame are the important cash crops. The town of Metema serves as an important trade gateway between Sudan and the Amhara Regional state. The economy of the district is predominantly agriculture. Gum and incense are important cash crops in the district.

The geological classifications of the district are manly dominated by tertiary and younger sediments and early tertiary volcanic rocks (Mohr, 1966; Merla *et al*., 1979). The soils in flat land areas are dominantly Chromic and Pellic vertisols, while the soils in hillsides are Chromic and Orthic Luvisols (EMA, 1988).

The district has a total population of 110,231, increased by 100% over the 1994 census (54,913) (CSA,

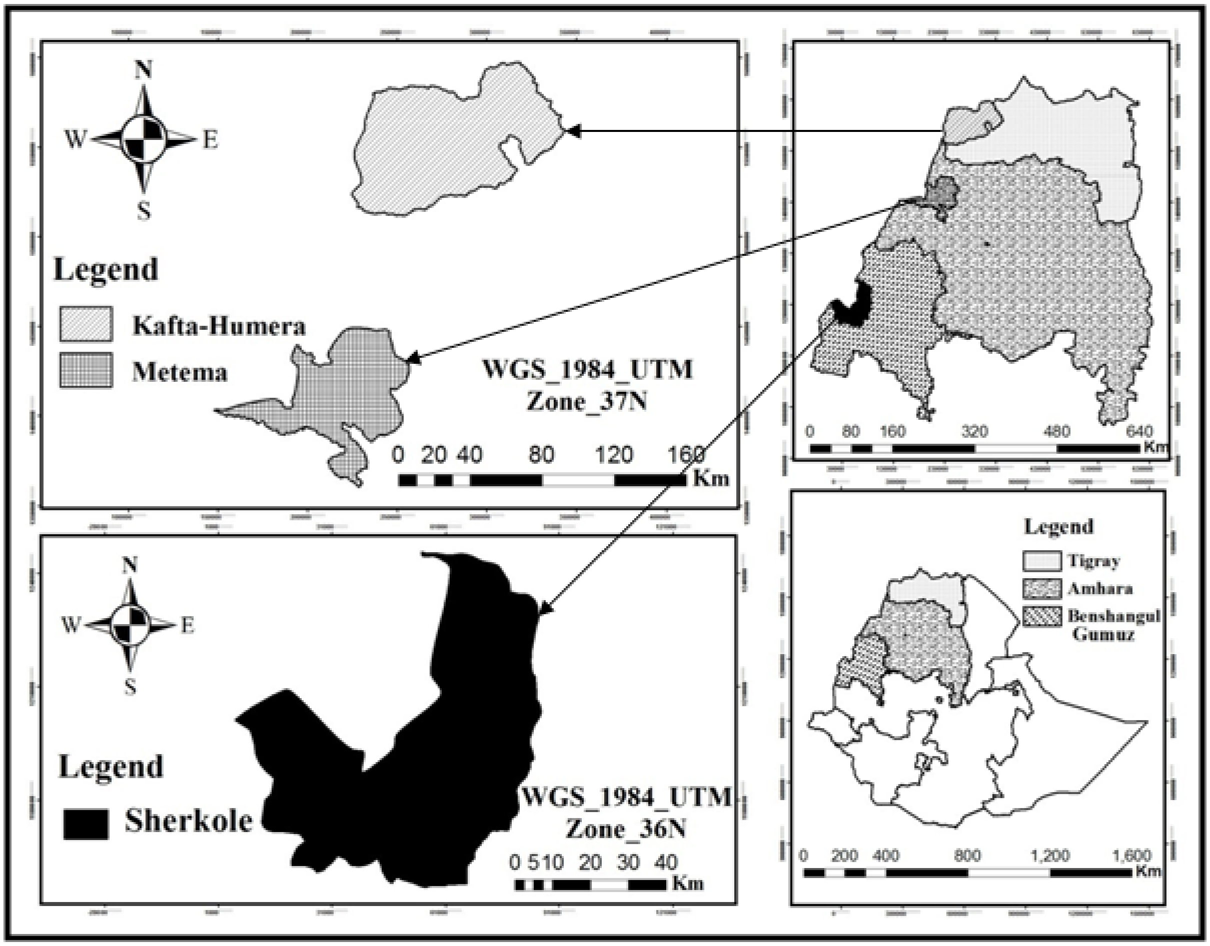

Figure 1. Location and Map of the Study areas (Kafta Humera, Metema and Sherkole Districts)

2007). A total of 29,378 households were counted in the district and the average size of the household was 3.75 persons. The district covers a total area of 380,677 ha and has a population density of 29 persons/km^2.

c) Sherkole

Sherkole is located in Benshangul Gumuz regional state in western Ethiopia (Figure 1) at 34^0 28' 48.29'' to 35^0 13' 3.14'' E and 10^0 26' 18.98'' to 11^0 14' 25.65'' N with an altitude range between 500 and 1000 m a.s.l. The total annual rainfall varies from 900-1200 mm with mean annual temperature ranging in 10.8-42^{0}C.

The geololy of the study area is chacrterized mainly by the occurrence of intrusive rock (Mohr, 1966; Merla *et al.*, 1979). Dominatly occurred soils in the study area include among others Dystic Nitosols and Calcaric and Eutric Fluvisols (EMA, 1988). The climate of the study area is characterized by semi-arid climatic condition (WBISPP, 2004). The total land area of the district is 351,857 ha, out of which 6.89% cultivated land, 55.25% wooded and shrub land, 18.66% grass land and 19.20% other land uses.

The total population of the district is about 19,992 with 4,237 households. Sherkole has a population density of 6 persons/km^2, which is far below compared to the national average (77.72 persons/km^2) (CSA, 2007).

Remote Sensing and GIS

Data Acquisition and Collection

The data used in this study were Remotely Sensed (RS) images. Three dates (1985, 1995 and 2010) of Landsat imageries were acquired (Source: http://landcover.org) and their brief descriptions are summarized in Table 1.

i. Image Pre-processing

Both geometric rectification and image enhancement were conducted. Geometric correction transforming image pixel positions by correcting for the optical geometry and to compensate for distortions caused by the motion of the image platform and shape of the terrain. In this study, the georeferencing strategy adopted was an

Table 1. Description of remote sensing data that were used in the Study

Sensors	Study Area	Path and Row	Bands	Pixel Size (m)	Observation Date
Enhanced Thematic Mapper (ETM)	Kafta Humera	p170 r50 & 51	7	30*30	1985
ETM	Metema	p170 & 171 r51	7	30*30	1995
ETM	Sherkole	p171 r52 &53	7	30*30	2010

Table 2. Description of Land Use and Land Cover Types Identified

Land Use and Land Cover Classes	LULC Description
Woodland	Land covered with relatively tall trees, at least have 20% canopy coverage including integral open space and felled areas that are awaiting restocking, the predominant species found in the area was *Boswellia papyrifera*
Shrub/Bush land	Land covered by small trees, bushes, and shrubs, and in some cases such lands are mixed with grasses; It is less dense than the woodland
Grass land	Small grasses are the predominant natural vegetations. It also includes land with scattered or patches of trees and this land cover is used for grazing and browsing
Agricultural Land	Areas allotted to extended rain fed crop production, mostly oil seed, cereals and pulses are managed
Bare land & Settlement	Land, which is mainly covered by bare soil and rock out crops and land covered by structures, which included towns and rural villages
Water Body	Lakes, rivers and streams

image-to-image registration. Primarily, 1:250,000 digital topographic maps of the study areas were used to register a 2010 ETM images for the Universal Transverse Mercator (UTM) geographic projection using datum Adindan Ethiopia. Road and river intersections in the images were used for the purpose. In turn, the registered output images were used as references to register the remaining images of 1995 and 2010 and finally all images were clipped with the boundary of the study area for further processing. Image enhancement was used to increase the details of the images by assigning the image maximum and minimum brightness values to maximum and minimum display values (Lillesand *et al,* 2008). Landsat data are 8-bit data and the Digital Numbers (DNs) have values from 0 to 255. Accordingly, the original low dynamic ranges of the images were stretched to full dynamic range using histogram equalization and this made visual interpretation better.

ii. Image Classification and Analysis

In this study, both unsupervised and supervised image classification methods were adopted (Rogan & Chen, 2004). Unsupervised classification was first carried out to have an idea of representing the overall land use and land cover clusters of pixels. And then supervised classification was employed to categorize the images using ground truths (training areas) which were defined based on the results of unsupervised classification (the cluster of pixels) and ancillary data (Google Earth).

For this study, six land use and land cover types were identified for the purpose of monitoring and mapping (Table 2). For this identification, some of the land use and land cover classes was required frequent field visits and discussions with farmers and also consulted secondary data, to have a clear understanding of the main categories of land use and land cover as well to find out what types of changes are expected over time.

iii. Accuracy Assessment

The classified land use and land cover maps may contain some sort of errors because of several factors, from classification technique to the methods of satellite data capture. In order to use the classified maps, the errors must be quantitatively evaluated through classification accuracy assessment and intended to produce information that describes reality. Therefore, an accuracy classification assessment was performed through the standard method (Congalton, 1991). Firstly, in the processes of assessment, references (samples) were identified from Google Earth and using Global Positioning System (GPS) from the field, and references were independent of the ground truths that are used in the classification scheme. Thus, total accuracy, and Kappa statistics were computed. In principle, all the output maps have to meet the minimum 85% accuracy (Anderson *et al*., 1976).

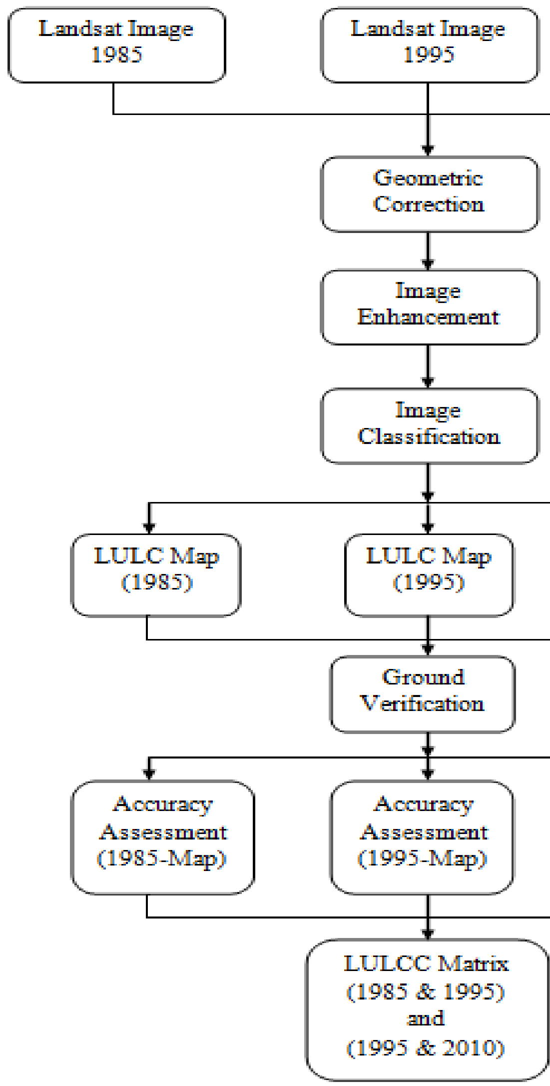

Figure 2. The General Framework for the Study of LULC

iv. Change Detection

Visual comparison of features and matrix analysis (image differencing) were adopted to determine the land use and land cover change detection (Lu *et al*, 2004). Areas that are converted from each class to any of the other classes were computed and the change directions were also determined.

RESULTS

Land Use and Land Cover Dynamics in Kafta Humera

The accuracy assessment was conducted for all the classified imageries (maps) via a standard method. The producer's, user's and total accuracy and the Kappa statistics were computed. In general all the maps met the recommended minimum 85% accuracy (Table 3).

In all study years much of the district coverage was the natural vegetation, including wood land, shrub land and grass land (Table 4 and Figure 3); while the classes of wood land and agricultural land comprised the largest share of the total area. The study revealed the woodland was intact in the first study period while overtime increased trends of conversion of wood land to agriculture was observed. As a result, the share of agricultural land increased from 23.5% (148772.34ha) in 1985 to 28.23% (178640.37 ha) in 1995, to 39.11% (247509 ha) in 2010. Expansion in the extent of bare land and settlement also followed the same trend as agricultural land did, and its area coverage in 2010 was about 1.2 times higher than its original cover of 1985. In

Table 3. LULC classes and accuracy assessment of the classified images of Kafta Humera

Classes	Accuracy (%)					
	1985		1995		2010	
	Producer's	User's	Producer's	User's	Producer's	User's
Agricultural land	94.71	80.39	85.88	90.91	90.45	88.64
Bare land & Settlement	88.17	86.36	81.14	84.09	84.08	85.71
Wood land	90.68	88.64	82.50	87.18	86.50	88.1
Shrub land	83.39	80	81.75	78.26	85.30	82.22
Grass land	85.00	87.8	97.78	81.4	81.86	83.33
Water body	83.21	100	85.88	100	100	100
Overall accuracy	87.2		86.97		88	
Kappa coefficient	0.84		0.84		0.86	

Table 4. Areas of LULC of Kafta Humera District between 1985 and 2010

Land Use Type	1985		1995		2010	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agricultural land	148772.34	23.51	178640.37	28.23	247509	39.11
Bare land & Settlement	27832.68	4.40	28433.61	4.49	33796.62	5.34
Wood land	266879.88	42.17	225538.11	35.64	162973.26	25.75
Shrub land	96540.03	15.25	108364.5	17.12	107579.07	17.00
Grass land	92158.29	14.56	91409.94	14.44	80667.99	12.75
Water body	694.53	0.11	491.22	0.08	351.81	0.06

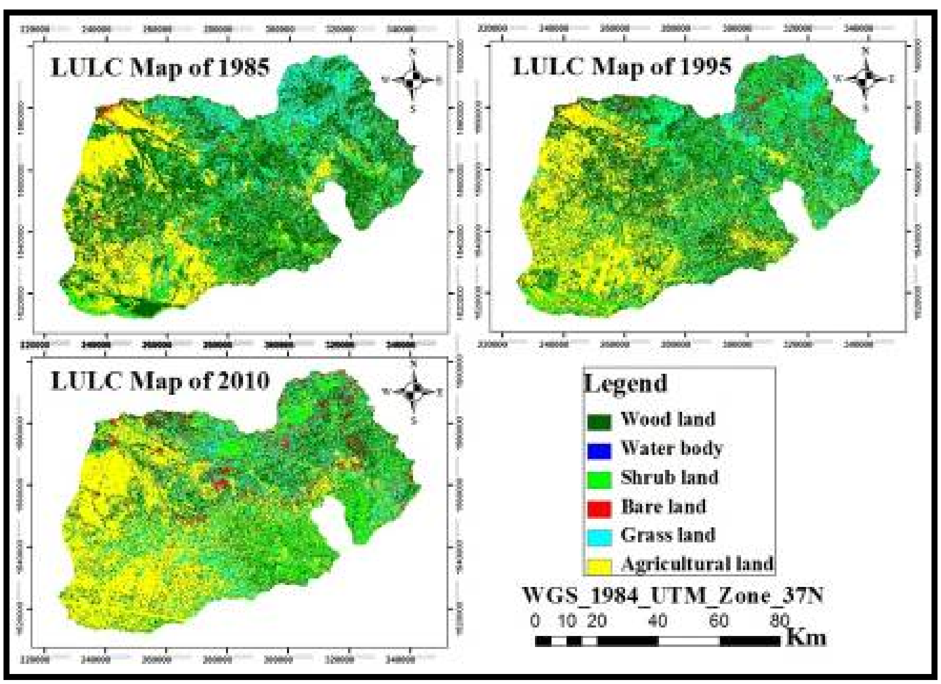

Figure 3. LULC Maps of Kafta Humera District for the Years 1985, 1995 and 2010

Table 5. LULC Change Matrices of the Kafta Humera District (1985-1995)

Change from LULC 1985 (ha)	Change to LULC 1995 (ha)						Total
LULC	Agricultural land	Bare land & Settlement	Wood land	Shrub land	Grass land	Water body	
Agricultural land	132624	874	14230.1	866.31	178	0	148772.34
Bare land & Settlement	606.15	19469.2	2483.63	2137.2	3136.47	0	27832.68
Wood land	42365.7	4603.29	179023	21141.9	19745.9	0	266879.88
Shrub land	1593.61	1629.52	13862.5	64653	14801.4	0	96540.03
Grass land	1450.98	1822.38	15938.8	19459.8	53486.4	0	92158.29
Water body	0	35.19	0	106.29	61.83	491.22	694.53
Total	178640.37	28433.61	225538.11	108364.5	91409.94	491.22	632877.75

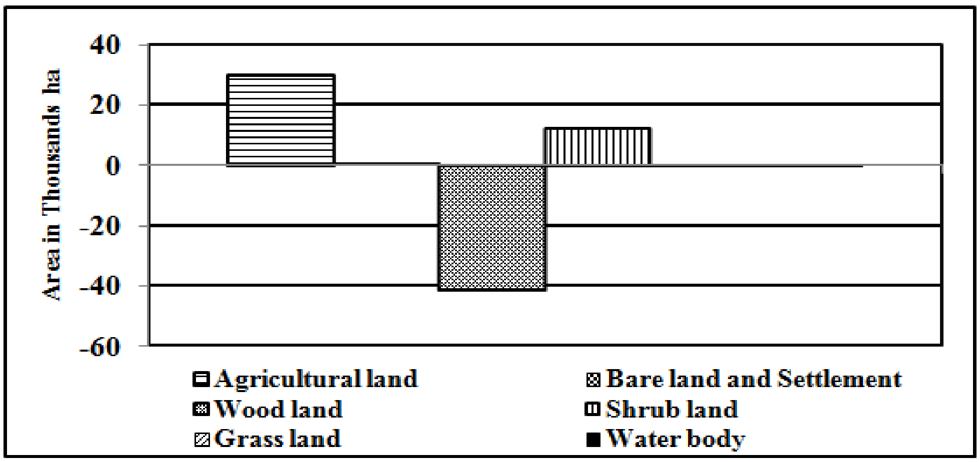

Figure 4. LULC Conversion in Kafta Humera District between 1985 and1995

Figure 4. LULC Conversion in Kafta Humera District between 1985 and1995
Note: The negative values indicate a decline while the positive values indicate the expansion of that particular land use and land cover.

contrast, the wood land cover declined continuously from its level of 42.17% in 1985 to 35.64% in 1995, further to 25.75 % in 2010. However, areas of shrub land, grass land and the water bodies showed inconsistent trends of conversions.

The land use change matrices depict the changes in extent and directions in LULC classes. As evident from Table 5 and Figure 4, there has been substantial increase in the area of agricultural land (178640.37 ha) during 1985-1995, although some portion of its extent was converted to bare land (874 ha), to wood land (14,230.1 ha), to shrub land (866.31 ha) and to grass land (178 ha). In contrast, a shrinkage was evident in the area of wood lands (41,341.8 ha) between 1985 and 1995, although, at the same time it gained areas from the classes of bare land and settlement (4603.29 ha), shrub land (21141.9 ha), and grass land (19745.9 ha). The conversion to wood land did not compensate its decline during the whole study period (1985-2010).

In the second study period, 1995-2010, similar patten has been obesrved as the frist one, the area of agricultural land increased by 68868.6 ha although its area simultaneously was lost to bare land (845 ha), wood land (9704 ha), shrub land (367.09 ha) and grass land (110.35 ha) (Table 6 and Figure 5). As seen in the Table, the most important contributors to the increase of agricultural land were wood land (60,062.96 ha) and shrub land (15,551.72 ha).

Regarding LULC rate of change, agricultural land has been remarkably increased by 2.0% annually (Table 7) during 1985-1997; while during 1997-2010, the annual increase was 2.6%. In contrast, the annual rate of wood land and grass land depletion were susbtatially increased from 1.6% in 1985-1997 to 1.9% in 1997-2010.

Table 6. LULC Change Matrices for Kafta Humera District (1995 – 2010)

Change from LULC 1995 (ha)	LULC	Change to LULC 2010 (ha)						Total
		Agricultural land	Bare land & Settlement	Wood land	Shrub land	Grass land	Water body	
	Agricultural land	167613.93	845	9704	367.09	110.35	0	178640.37
	Bare land & Settlement	1080	11034.5	6366.6	5411.61	4540.86	0	28433.61
	Wood land	60062.96	9248.59	124986.66	21106.78	10133.1	0	225538.11
	Shrub land	15551.72	6178.31	11188	61306.78	14139.7	0	108364.5
	Grass land	3200.39	6427	10728	19375.29	51679.3	0	91409.94
	Water body	0	63.18	0	11.52	64.71	351.81	491.22
	Total	247509	33796.62	162973.26	107579.07	80667.99	351.81	632877.75

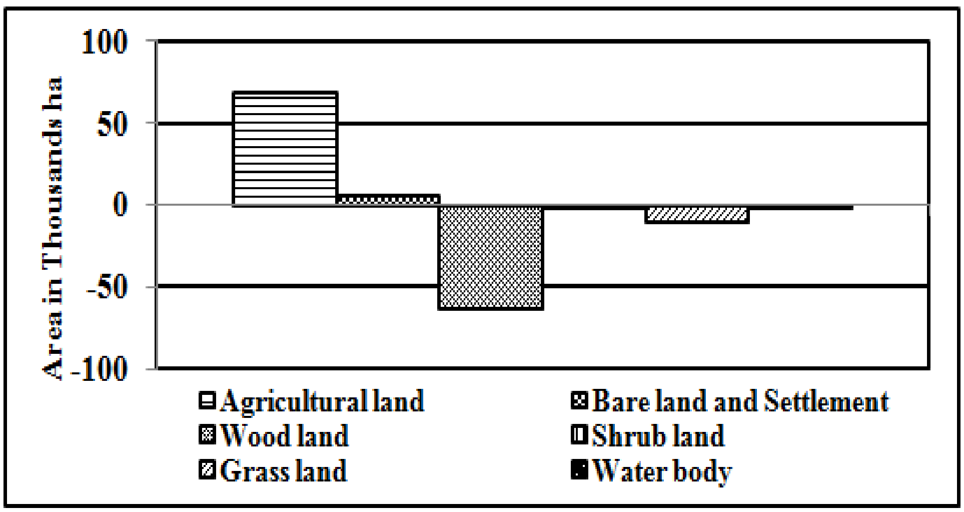

Figure 5. LULC Change of Kafta Humera District between 1995 and 2010

Table 7. Rate of Changes in LULC Classes (1985-2010)

Land Use and Land Cover	1985 to 1995		1995 to 2010	
	ha/year	%	ha/year	%
Agricultural land	2986.80	2.01	4591.24	2.57
Bare land & Settlement	60.09	0.22	357.53	1.26
Wood land	-4134.18	-1.55	-4170.99	-1.85
Shrub land	1182.45	1.22	-52.36	-0.05
Grass land	-74.84	-0.08	-716.13	-0.78
Water body	-20.33	-2.93	-9.29	-1.89

Land Use and Land Cover Dynamics in Metema

Like the previous district, the accuracy assessment of all the classified imageries from Metema district was conducted in a standard way. For all maps, the producer's, user's and total accuracy and the Kappa statistics were computed. Overall, the maps met the required minimum 85% accuracy (Table 8).

Table 8. LULC classes and accuracy assessment of the classified images of Metema

Classes	Accuracy (%)					
	1985		1995		2010	
	Producer's	User's	Producer's	User's	Producer's	User's
Agricultural land	87.08	94.87	92.63	88.89	93.21	93.02
Bare land & Settlement	81.54	87.18	88.42	86.36	86.56	86.05
Wood land	90.60	82.98	81.24	89.47	85.16	92.31
Shrub land	84.08	80	76.79	76.74	81.64	81.4
Grass land	84.80	77.88	83.10	80	87.20	80.85
Water body	93.91	100	100.00	100	100.00	100
Overall accuracy	87.15		86.91		88.94	
Kappa coefficient	0.84		0.84		0.87	

For the whole study period, much of the district coverage was the natural vegetation, including wood land, shrub land and grass land (Table 8 and Figure 5); while the classes of shrub land (30.1%) in 1985 and 30.94% in 1995, and agricultural land (42.21%) in 2010 comprised the largest share of the total area. The study also revealed increased trends of conversion of wood land to agricultural land. As a result, the share of agricultural land increased from 24.13% (91889.73ha) in 1985 to 42.21% (160699.41 ha) in 2010. Increases in the extent of bare land and settlement also followed similar trend as agricultural land lead through, and its area coverage in 2010 was about 1.4 times higher than its original cover of 1985. Like the previous district, the wood land cover was diminishing continuously from its level of 28.46% (108333.54 ha) in 1985 to 16.66% (63423.09ha) in 2010. However, areas of shrub land and grass land showed inconsistent pattern of conversions.

The land use change matrices depicted the changes in the extent and directions in LULC classes. As evident from Table 10 and Figure 6, there have been a remarkable increases in the area of agricultural land (25220.43 ha), bare land and settlement (5344.2 ha), shrub land (3201.39 ha), and grass land (949.41 ha) during the first study period although some portion of their extents were converted to other LULC classes. In contrast, the only shrinkage was evident in the extent of wood lands (34482.06 ha) however the added area from the classes of agricultural land (3545.34 ha), bare land and settlement (5000.49 ha), shrub land (19287.99 ha) and grass land (5120.67 ha) could not compensated its losses in the course of the first period.

In the second study period (1995-2010), the areas of agricultural land, and bare land and settlement have been increased by 43589.25ha and 5146.02ha respectively despite their initial areas in 1995 simultaneously were lost to wood land, shrub land and grass land (Table 11 and Figure 7). As seen in the Table 10, the most important contributors to the increase of agricultural land, and bare land and settlement were wood land and shrub land. Thus, from all classes in the district, wood land (27115.11ha) in the second period also noticeably continued to be the major area loser to agricultural land while shrub land (9897.84ha) to the bare land and settlement. In contrast, wood land, shrub land and grass land classes were lost their original extents and transformed to other classes.

With regard to the annual rate of LULC changes, in the first study period, agricultural land as an important class for smallholders has been remarkably increased with 2522.04 ha/year rate (Table 12) while in the second period the rate increased by 2905.95 ha/year. In contrast to the agricultural land, the annual rate of wood land depletion was decreased by 5 folds in the second study period as compared to the 1985-1997. .

Land Use and Land Cover Dynamics in Sherkole

Likewise the other two districts, for Serkole, the accuracy assessment of all the classified imageries were conducted in a standard way. For all images, the produce's, user's and total accuracy and the Kappa statistics were computed. In general, all images met the required minimum 85% accuracy (Table13).

For the whole study period, much of this district also covered with natural vegetation, including wood land, shrub land and grass land (Table 14 and Figure 8); while the classes of woodland and shrub land comprised the largest share of the total area in all times. The study also revealed increased trends of conversion of much of wood land area to bareland and settlement, and agricultural land. As a result, the share of agricultural land increased from 3.53% (16749.09 ha) in 1985 to 6.89% (24246.27 ha) in 2010 and the coverage of bareland and settlement surprisingly increased from 7.22% (36622.35 ha) in 1985 to 18.69% (65745.63 ha) in 2010. Like the previous two districts, the wood land cover was diminishing continuously from its level of 42.08% (148055.67 ha) in 1985 to 24.39% (85800.87 ha) in 2010. However, areas

Table 9. Areas of LULC of Metema District for the Years 1985, 1995 and 2010

Land Use Type	1985		1995		2010	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agricultural land	91889.73	24.14	117110.16	30.76	160699.41	42.21
Bare land & Settlement	26137.71	6.87	31481.91	8.27	36627.93	9.62
Wood land	108333.54	28.46	73851.48	19.40	63423.09	16.66
Shrub land	114570.9	30.10	117772.29	30.94	93076.65	24.45
Grass land	39300.93	10.32	40250.34	10.57	26651.25	7.00
Water body	444.51	0.12	211.14	0.06	198.99	0.05

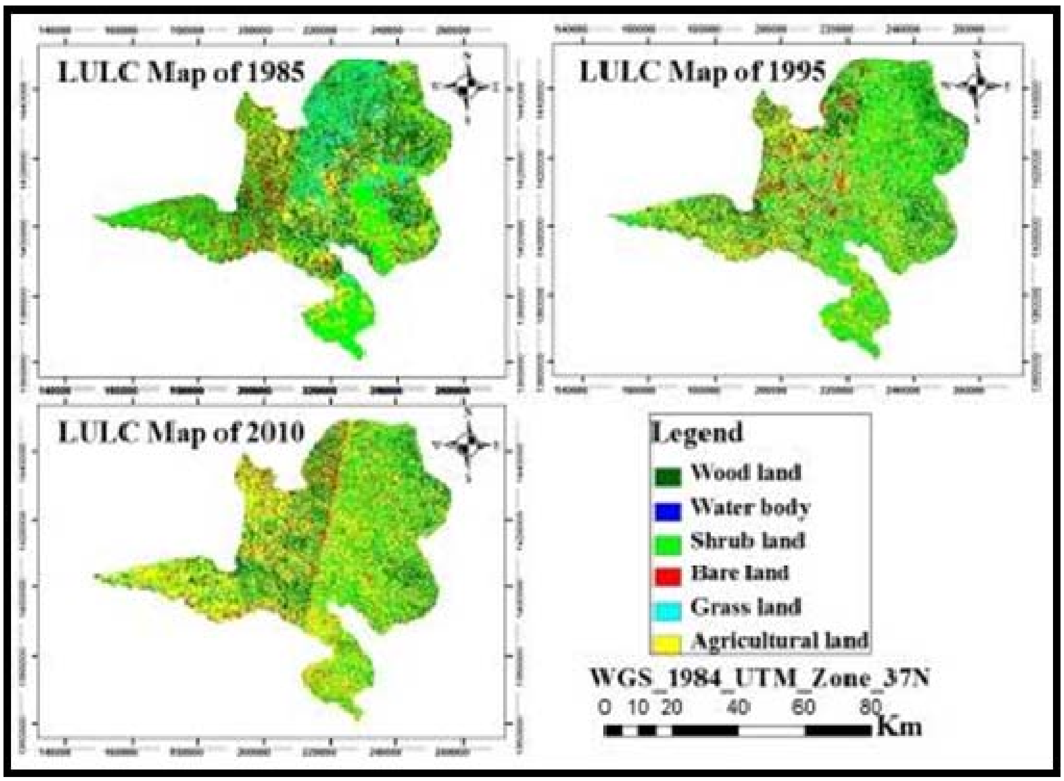

Figure 5. LULC Map of Metema District for the Years 1985, 1995 and 2010

of shrub land and grass land showed expected inconsistent pattern of conversions.

The change matrices depicted the changes in extent and directions in LULC classes. As evident from Table 15 and Figure 9 there has been a remarkable increase in the area of agricultural land (16749.09 ha), bare land and settlement (36622.35 ha) and shrub land (119077.74 ha during the first study period despite some portion of their initial extents were converted to other LULC classes. Whereas, a simultaneous shrinkage was observed in the area of wood lands (12108.8 ha), even though considerable area of land added to it from shrub land (19359.42 ha) and grass land (16492.86 ha).

In 1995-2010, the areas of agricultural land, bare land and settlement, and grass land have been increased by 7497.18 ha, 29123.28 ha and 23463ha respectively, despite their initial areas of 1995 were simultaneously lost to wood land, shrub land and grass land (Table 16 and Figure 10). As shown in Table 16, the most important contributors to the increase of agricultural land, and bare land and settlement were wood land while shrub land lost to grass land. Accordingly, wood land (5060.19 ha), just like other districts, noticeably continued to be the major area contributor to agricultural land.

With regard to the annual rate of LULC changes, in the first study period, the rate of wood land depletion was

Table 10. LULC Change Matrices for Metema District (1985-1995)

Change from LULC 1985 (ha)	Change to LULC 1995 (ha)						Total
LULC	Agricultural land	Bare land & Settlement	Wood land	Shrub land	Grass land	Water body	
Agricultural land	83961.95	713.36	3545.34	1865.47	1803.61	0	91889.73
Bare land & Settlement	2254	12288.61	5000.49	5296.05	1298.56	0	26137.71
Wood land	15315.3	7163.82	40896.99	34688.43	10269	0	108333.54
Shrub land	10033	8279.07	19287.99	64670.45	12300.39	0	114570.9
Grass land	5545.91	2889.45	5120.67	11167.83	14577.07	0	39300.93
Water body	0	147.6	0	84.06	1.71	211.14	444.51
Total	117110.16	31481.91	73851.48	117772.29	40250.34	211.14	380677.32

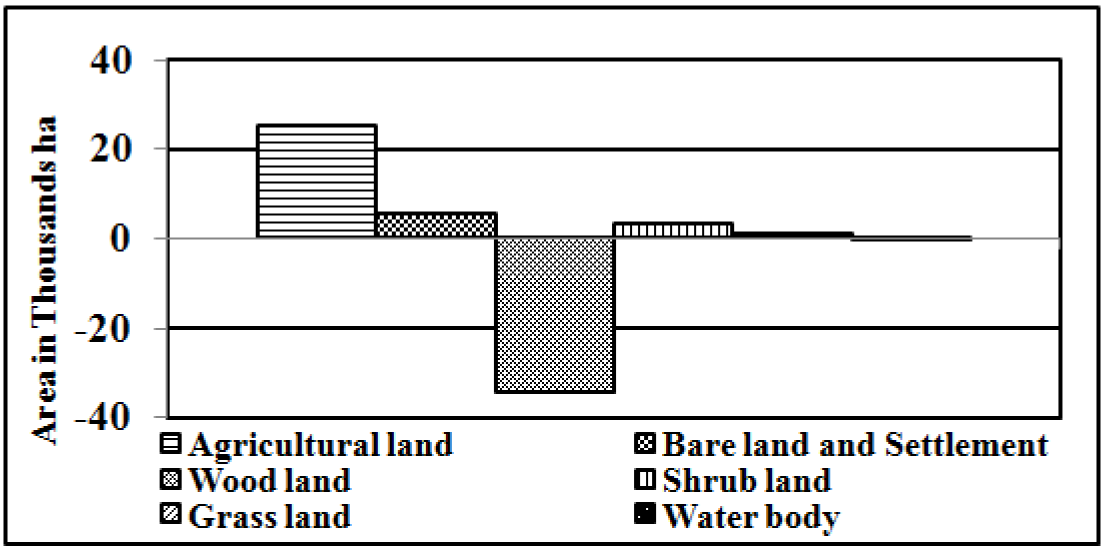

Figure 6. LULC Change for Metema District (1985-1995)

Table 11. LULC Change Matrices for Metema District (1995-2010)

Change from LULC 1995 (ha)	Change to LULC 2010 (ha)						Total
LULC	Agricultural land	Bare land & Settlement	Wood land	Shrub land	Grass land	Water body	
Agricultural land	111568.87	431.98	2591.22	625.6	1892.49	0	117110.16
Bare land & Settlement	3133.84	16245.77	2889.18	6779.79	2433.33	0	31481.91
Wood land	27115.11	5172.22	31017.43	5581.69	4965.03	0	73851.48
Shrub land	12968.4	9897.84	20834.6	65732.59	8338.86	0	117772.29
Grass land	5913.19	4877.55	6090.66	14352.53	9016.41	0	40250.34
Water body	0	2.57	0	4.45	5.13	198.99	211.14
Total	160699.41	36627.93	63423.09	93076.65	26651.25	198.99	380677.32

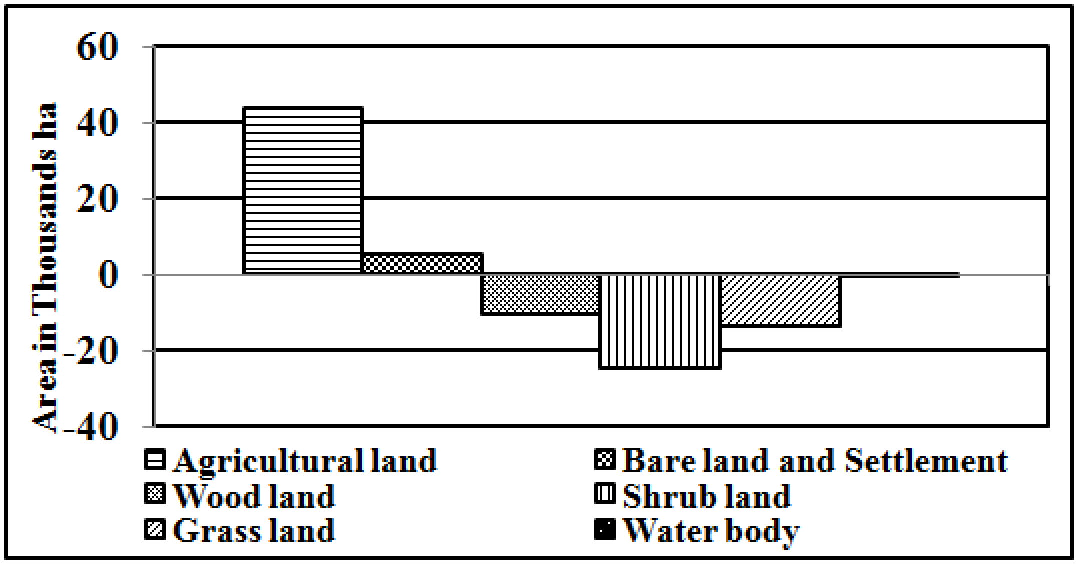

Figure 7. LULC Change for Metema District (1995-2010)

Table 12. Rate of Changes in LULC Classes (1985-2010)

Land Use and Land Cover	1985 to 1995		1995 to 2010	
	ha/year	%	ha/year	%
Agricultural land	2522.04	2.74	2905.95	2.48
Bare land & Settlement	534.42	2.04	343.07	1.09
Wood land	-3448.21	-3.18	-695.23	-0.94
Shrub land	320.14	0.28	-1646.4	-1.40
Grass land	94.94	0.24	-906.61	-2.25
Water body	-23.34	-5.25	-0.81	-0.38

Table 13. LULC classes and accuracy assessment of the classified images of Sherkole

Classes	Accuracy (%)					
	1985		1995		2010	
	Producer's	User's	Producer's	User's	Producer's	User's
Agricultural land	84.02	100	90.03	100	93.77	97.56
Bare land & Settlement	86.37	92.31	83.33	87.5	4.08	91.89
Wood land	91.97	75.47	86.33	74.51	89.94	79.59
Shrub land	84.06	76.6	84.35	83.72	85.14	80.43
Grass land	80.38	79.07	82.77	81.4	82.51	79.55
Water body	97.50	100	100.00	100	95.27	100
Overall accuracy	87.24		87.86		88.17	
Kappa coefficient	0.83		0.85		0.85	

Table 14. Areas of LULC of Sherkole District for the Years 1985, 1995 and 2010

Land Use Type	1985		1995		2010	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agricultural land	12431.34	3.53	16749.09	4.76	24246.27	6.89
Bare land & Settlement	25394.4	7.22	36622.35	10.41	65745.63	18.69
Wood land	148055.67	42.08	135946.89	38.64	85800.87	24.39
Shrub land	115767.9	32.90	119077.74	33.84	108567	30.86
Grass land	48962.61	13.92	42207.3	12.00	65670.3	18.66
Water body	1245.15	0.35	1253.7	0.36	1827	0.52

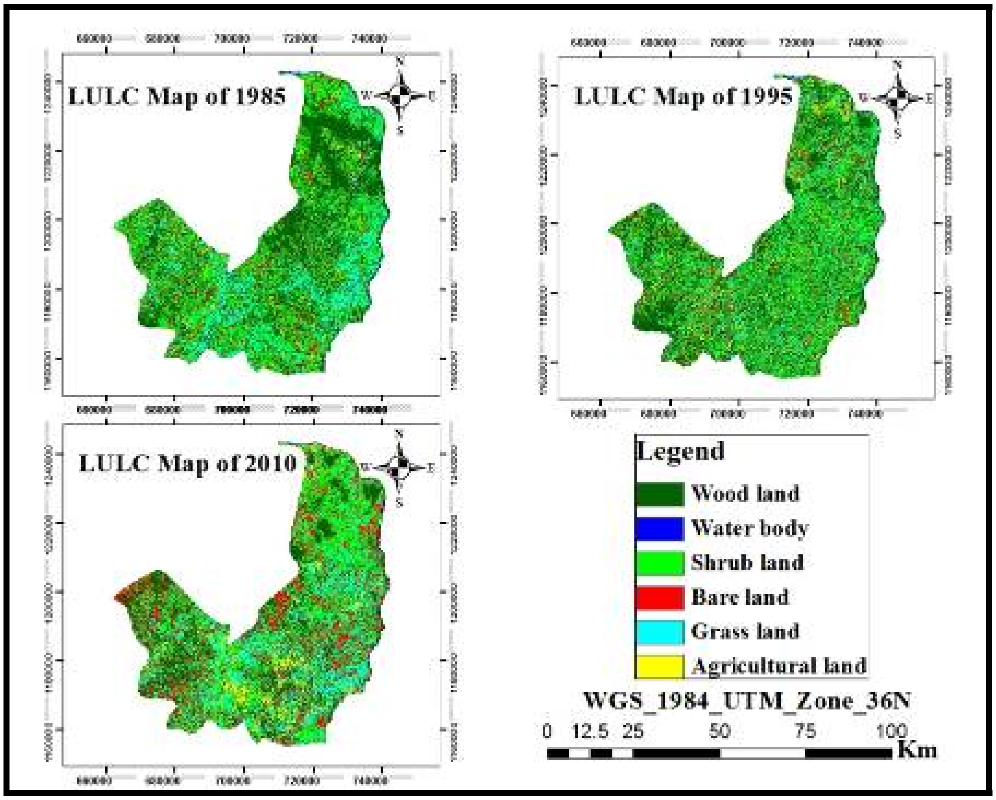

Figure 8. LULC Map of Sherkole District for the Years 1985, 1995 and 2010

Table 15. LCLC Change Matrices for Sherkole District (1985-1995)

	LULC	Change to LULC 1995 (ha)						Total
		Agricultural land	Bare land & Settlement	Wood land	Shrub land	Grass land	Water body	
Change from LULC 1985 (ha)	Agricultural land	9486.89	364.41	943.23	487.19	1149.62	0	12431.34
	Bare land & Settlement	306.92	4080.22	9387.72	8539.92	3079.62	0	25394.4
	Wood land	4422.85	13719.96	89763.66	23063.42	17085.78	0	148055.67
	Shrub land	1136.1	12557.43	19359.42	68284.8	14421.6	8.55	115767.9
	Grass land	1396.33	5900.33	16492.86	18702.41	6470.68	0	48962.61
	Water body	0	0	0	0	0	1245.15	1245.15
	Total	16749.09	36622.35	135946.89	119077.74	42207.3	1253.7	351857.07

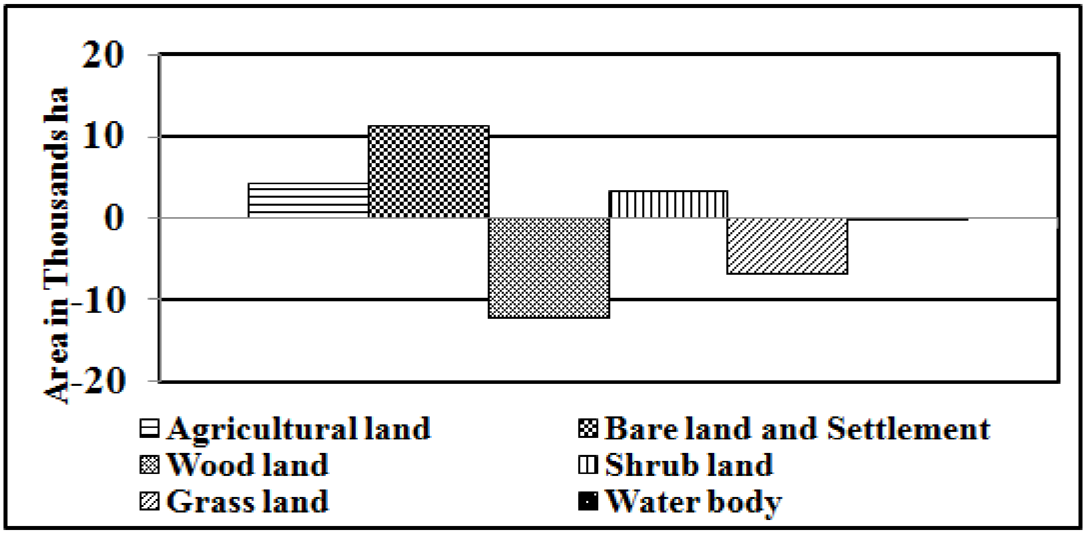

Figure 9. LULC Change for Sherkole District (1985-1995)

Table 16. LULCC Matrices of Sherkole District (1995-2010)

Change from LULC 1995 (ha)	Change to LULC 2010 (ha)						Total
LULC	Agricultural land	Bare land and Settlement	Wood land	Shrub land	Grass land	Water body	
Agricultural land	13360.4	697.44	979.1	571.17	1140.99	0	16749.09
Bare land & Settlement	760	9173.48	6002.1	12468.6	8218.17	0	36622.35
Wood land	5060.19	26305.3	46139.9	37397.16	21044.3	0	135946.89
Shrub land	1955.58	21831.6	24024.3	46280.69	24737.5	248.13	119077.74
Grass land	3110.11	7737.85	8655.48	11849.38	10529.3	325.17	42207.3
Water body	0	0	0	0	0	1253.7	1253.7
Total	24246.27	65745.63	85800.87	108567	65670.3	1827	351857.07

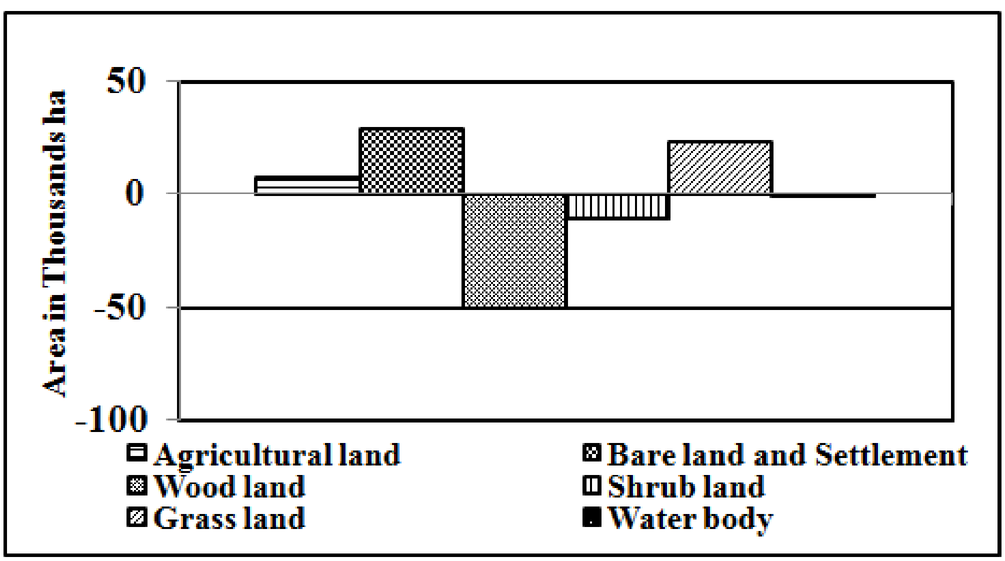

Figure 10. LULC Change for Sherkole District (1995-2010)

Table 17. Rate of Changes in LULC Classes (1985-2010)

Land Use and Land Cover	1985 to 1995		1995 to 2010	
	ha/year	%	ha/year	%
Agricultural land	431.78	3.47	499.81	2.98
Bare land & Settlement	1122.80	4.42	1941.55	5.30
Wood land	-1210.90	-0.82	-3343.10	-2.46
Shrub land	330.98	0.29	-700.72	-0.59
Grass land	-675.53	-1.38	1564.20	3.71
Water body	0.86	0.07	38.22	3.05

appreciably increased by 3 folds (3343.10 ha) in the second study period from the first (1210.90ha). In contrast to the wood land, agricultural land has been expanded in the first period with a rate of 3.47% (431.78ha) (Table 17) while in the second period the change rate was delined to 2.98% (499.81).

DISCUSSION

Six major land use and land cover types (Agricultural land, Bare land and Settlement, Wood land, Shrub land, Grass land, and Water body) were identified in all study areas. High values of overall classification accuracy (86.91%-87.26%) and kappa coefficient (0.83-0.84) were attained, these indicated a strong agreement between the classified LULC patterns and the geographical data (ground truths). Then it is possible to use the output maps that meet the requirements for the intended application.

Change in land use and land cover may result in wood land/forest clearance and land degradation that manifests in many ways depending on the magnitude of changes. For example, increase in demand for wood and fodder, reduction of biodiversity, reduced land productivity, low income generation capacity, influence in microclimate, water courses drying up, soil erosion incidences and gully formation (Teketay, 2001; Taddese, G., 2001; Taylor *et al*., 2002; Bewket and Sterk, 2005; Amsalua *et al*. 2007; Moges and Holden, 2009). All of these manifestations have potential impacts on land users who rely on the products and services from a healthy landscape for their living.

The land use and land cover changes that were detected in all study areas revealed, in general, the greater areas of wood land, shrub land and grazing land were transformed into agricultural land, and bare land and settlement. The latter definitely imply how changes in land use and land cover causes land degradation. The observed land use and land cover changes in the study area have both positive and negative impacts on the environment and socio-economic settings. For instance, the expansion of new cultivated lands in the study area was an advantage to landless farmers for subsistent farming in order to survive however this kind conversion is usually at the expense of the natural vegetations (grass land, shrub land and wood land) and similar conditions have been identified in Zeleke and Hurni, (2001), Geist and Lambin, (2004); Dessie and Christiansson, (2008) and Garedew *et al*., (2009).

Rapid population growth and new resettlement programs, commercial agricultural investments and poor land administration were identified as the driving forces for the dramatic expansion of agricultural land in space and time. For instance, in Kafta Humera and Metema, the class of agricultural land was dominated in the year 2010. This shows forced conversion of the larger part of the natural vegetation cover to agricultural land, and bare land and settlement, which were constantly increased in all the three study areas. In this regard, human activities are taken basically in to consideration for the expansion of huge agricultural lands through unplanned exploitation of forest resources for the spontaneously increased population.

Generally, the annual rate of the agricultural expansion in the study period was high and ranges between 2.65% in Sherkole and 3.8% in Kafta Humera, this result is in agreement with many studies in different part of the country and elsewhere in dry land conditions (Dwivedi *et al*, 2005; Garedew *et al*., 2009; Getachew *et al*, 2011; Kidane *et al*., 2012).

Forest cover change was triggered by various factors that undermine the forest use potential and its productivity, which may leads to irreversible deterioration. As mentioned forest land use and land cover change was the direct reflection in the dynamics of socio-economic development. Likewise, several factors stimulated by the activities of man and are responsible for massive conversion of natural vegetation into other land forms. All the factors such as the prevalence of various types of agricultural activities, forest exploitation, resettlement expansion, and income generation are directly or indirectly related to population growth. Therefore, in all study areas, the annual rate of woodland conversion to other lands in the study period was severe and ranges between 1.56% in Sherkole and 1.68% in Kafta Humera.

These results are in agreement with several studies (Bewket and Sterk, 2005; Emiru *et al*., 2012; Moges and Holden, 2009; Tsegaye *et al*., 2010) but forest-based poverty alleviation strategies may not be an option if business continuous as usual in the future.

Largely available land due to low population density promotes commercial agriculture and livestock rearing especially in Metema and Kafta Humera. Indeed, forests were mainly cleared for the purpose of commercial farmland expansion. The local farmers always keep livestock in large quantity as saving asset and little attention for their quality and production. Accordingly, this kind of practices could lead pasture lands vulnerable to over grazing and negatively influenced on forest natural regeneration as well. Key informants were stated that to keep a larger number of livestock in a given family is an indication of sources of wealth and status. Indeed, this mental attitude is not limited to the study area but commonly practice throughout Ethiopia (Kassa *et al*, 2002; Sandford and Ashley, 2008).

In most rural areas, fire wood and animal dung are the two most important sources of traditional household energy for cooking and heating (Amsalu *et al*., 2007; Garedew *et al*., 2009). Both key informants and forestry experts were reported that over the past recent years fire wood and charcoal were the most commercialized energy sources for rural and urban households in the region as their demands have been increased over time and they are the major causes of forest cover change and degradation. Sale of wood and wood products is a means of living for many resource poor individuals, especially jobless youths and women in the districts. Agricultural officers and forestry experts also reported that these groups of people illegally cut down trees from the forest area so as to supply large quantities of forest products for urban and rural dwellers through the nearby markets. Weak enforcement of forest regulation was also contributing for the aggravation and the swift forest destruction.

CONCLUSION AND IMPLICATIONS

The study has clearly demonstrated the potential of multi-temporal Landsat data and GIS in studying the land use and land cover dynamics. They are also useful tools to establish a decision support system and have a paramount importance for natural resource management and planning.

Agricultural land, and bare land and settlements have been tremendously increased, with a concomitant shrinkage in the area coverage of wood land. In general resettlements and commercial agricultural investments are responsible to the severe clearance of economically, socially and environmentally important natural vegetation of the dry forests.

Avoiding deforestation and wood land degradation through awareness would enhance livelihood diversification (e.g., through carbon trading); and this is an important future task of the regional governments and the local people to contribute to the global effort in climate change mitigation and simultaneously local livelihood benefiting from the carbon trading and other environmental services. The need for appropriate policies and truly participation of the local people in the sustainable management of wood land resources is important to safeguard the dry forests.

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