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Barana Babiso [α], Senbetie Toma [σ] & Aklilu Bajigo [ρ]

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Keywords: dynamics, land cover, land use, watershed, SLM.

I. Introduction

With the birth of agriculture, changes in land use/land cover (LU/LC) might first have occurred during the prehistoric period as the direct and indirect consequences of human actions with the burning of areas to enhance the availability of wild games and secure essential resources (Ellis and Pontius, 2012). It is worth mentioning here, however, that the current rates, extents and intensities of LU/LC changes are far greater than ever in history, driving unprecedented changes in the ecosystems and environmental processes at local, regional and global scales, LC conversions (i.e., the complete replacement of one cover type by another) are measured by a shift from one LC category to another as is the case in agricultural expansion, deforestation, or urban expansion (Liu *et al*., (2007). LC modifications are more subtle changes that affect the character of the land cover without changing its overall classification. Monitoring of land-cover conversion can be performed by a simple comparison of successive land cover maps. By contrast, the detection of subtle changes within land-cover classes requires a representation of LC where, the surface attributes vary continuously in space and time (De Fries *et al*., 1995). Remotely sensed (RS) time series data reveals that LC changes do not always occur in a progressive and gradual way, but they may show periods of rapid and abrupt change followed either by a quick recovery of ecosystems or by a non-equilibrium trajectory (Lambin *et al*., 2003); (Liu *et al*., (2007). In net shell, both land-cover modifications and rapid land-cover changes need to be better taken into account in LC change studies. Climate-driven land-cover modifications do interact with land-use changes.

LU/LC changes play a pivotal role in environmental and ecological changes and have both positive and negative impacts on a particular watershed. They also alter a catchment area's hydrological cycle by modifying rainfall, evaporation and runoff, particularly in small catchment areas (Cao *et al*., (2009).

In Ethiopia, the amount, rate and intensity of LU changes are very high and variable, implying that it is dynamic. For instance, over the past 41 years, agricultural land areas increased significantly at the cost of natural vegetation (woodland and shrub land) and in recent decade reductions in woodland (Kiros, 2008). Observations by (Kebrom & Hedlund, 2000). shows a decrease in the coverage of shrub lands, riverine vegetation, and forests, but areas under cultivation

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remained more or less unchanged on the highlands of Kallu District. The finding in the Derekolli Catchment, South Wollo also shows that the shrub lands declined by 58 percent between 1957 and 1986, with an increase in cultivated land by only 7 percent (Belay, 2002). LU/LC changes that occurred from 1971/72 to 2000 in Yerer Mountain and its surroundings manifested through an increase in cultivated land at the expense of the grasslands (Kahsay, 2004). In the semi- arid areas of the Central Rift Valley, in Keraru and Gubeta- Arjo, during the period 1973-2000, cropland coverage has increased and woodland cover lost (Ephrem, 2010).

LU changes have also been significant in recent years in Southern Ethiopia, including the area where this study was conducted (Gole and Denich, 2001). Large scale plantation expansion, communities' crop field expansion, and change in farming system was observed in Silte Zone (Daniel, 2008). The study at the Umbulo Catchment revealed the loss of 100 percent of high vegetation and a slight (10%) increase in vegetation between 1986 and 2000 (Awdenegest and Holden, 2009). Expansion of crop land area from 4,688ha in 1994 to 5,717ha in 1997, was in Chencha Zuria Woreda (Dwivedi *et al.,* 2005).

As a result of these land resource degradation processes, persistent negative changes are taking place in socio-economic well-being of the people and the environment, and land resources consequently giving birth to various forms of socio-economic challenges (Blaikie and Brookfield, 1987). Poor households are often virtually forced to over utilize natural resources for their daily subsistence. Thus, landless farmers colonize forests and even highly erodible hillsides. Rural households in fuel wood-deficit areas strip foliage and burn crop and animal residues for fuel rather than using them for fertilizer and this contributes to land degradation. A cycle of poverty and natural resource degradation is thus established (Repetto, 1987).

In the highlands of Ethiopia, LU/LC changes have reduced water retention capacity and increased the surface run-off and stream flow leading to loss of wetlands and dying of lakes (Alemayehu and Arnalds 2011). Indeed such complications imply the need for call for adoption for sustainable land management (SLM) practices. Hence, LU/LC change time series analysis is significant, not only for the sustainable management of land resources, but also for the projection of future LU trajectories (Long *et al.,* 2008). Therefore, knowledge of LU/LC change is essential in decision-making in relation to a wide range of issues, such as for reversing land degradation, deforestation, and climate change (Kiros, 2008). Improving the understanding of LU/LC dynamics can lead to the projection of future LU/LC changes and to more appropriate policy interventions for achieving better land management. Generally, determining the effects of LU/LC change depends on an understanding of past LU practices, current LU/LC patterns, and projections of future LU/LC.

In Ethiopia, various studies have been conducted on LU/LC changes mainly in Northern highlands. However, very few studies have been conducted in Southern Ethiopian highlands to monitor and quantitatively describe LU/LC dynamics. Even the few studies conducted in Southern Ethiopian highlands have not so far been studied with requisite focus to Wallecha watershed. Basic data on the extent and trend of LU/LC changes in wallecha watershed that would help for planning and adoption of SLM practice to minimize the extent and curve the trend of dynamic LU/LC changes are scanty. It is, therefore, the intention of this study to narrow, if not to fill, this gap and provide an in depth understanding of the patterns of LU dynamics and implications for planning appropriate land management in the watershed, so that ways will be sought to reverse the trend.

II. Objectives

In the present study an attempt has been made to assess the spatial and temporal dynamics of LU/LC at Wallecha Watershed during the period from 1984 to 2010; and examine the implications of observed LU/LC changes on sustainable land management (SLM).

III. Materials and Methods

a) *The study Area*

Wallecha Watershed is found to the North West of Lake Abaya in the Southern Highlands of Ethiopia. Astronomically, it is located between 6º53′30″ and 7º4′30″N latitudes and 37º48′0″ and 37º59′0″E longitudes with a total area of 10,116 hectares (*Figure 1*). It located at about 350 Km south of Addis Ababa, the national capital, and 153 Km southwest of Hawassa, the regional capital.

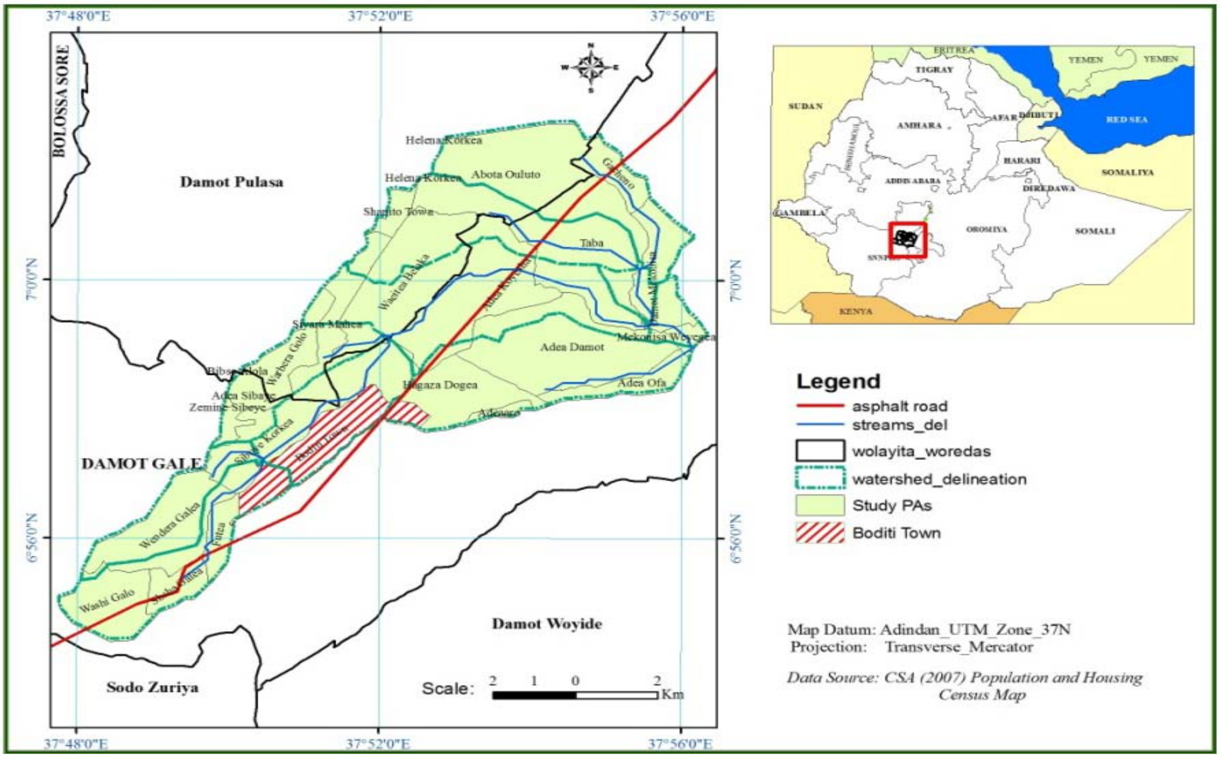

Figure 1: Location Map of Wallecha Watershed (Source: Extracted from Ethio-GIS)

i. *Physical Characteristics*

It is demonstrated with the DEM (Digital Elevation Model) of the watershed, which is clipped from SRTM (Shuttle Radar Topographic Mapping), that the northern and the central parts of the study watershed are flat with little variation in the altitude, whereas most of the south western part is highly rugged. The altitude ranges from 1750 m.a.s.l, at the north eastern part to 2835 m.a.s.l in south western part around the escarpment. The slope steepness of the area ranges from 0 to 68 percent ranging from gentle / flat to very steep slopes. Larger part of the watershed in fact lies on slope of greater than 15 percent and each having its own implications for conservation treatments.

As to the drainage of the watershed, numerous small temporary/ ephemeral streams which appear in the rainfall season and some permanent rivers enable efficient system of drainage. Major intermittent streams that join the watershed include: Borodo, Helame and Kiljijo at the foot of Mount Damota, but flow longer distances in Damot Gale and Damot Woyde Woredas in the north easterly direction before joining Bilate River which ends in Lake Abaya.

According to the traditional agro-climatic zonation of Ethiopia, which is based on overlaying rainfall, temperature and altitude, the study watershed is identified as having Dega and *Weina Dega* agro-climatic zones. The *Dega* comprises areas elevated above 2300m and covers about 10.8 percent of the area. The *Weina Dega* ranging from 1751-2300m covers about 89.2 percent of the watershed. However, these diversified landforms are highly interactive and related to each other via drainage systems and socio-cultural condition.

The watershed experiences bi-modal rainfall with annual average of about 1250mm. This enables a length of growing period of almost 300 days. The farmers carry out two cycles of seasonal cropping (the *gabba* during the short rainy season from February to July and the *sila* during the long rainy season from August to December) and sometimes an inter season cycle from December to March. The mean annual temperatures fluctuate between 16 and 20°C all along the year.

The original vegetation type of the watershed was woodland savanna vegetation where scattered trees and shrubs occurred in herbaceous elements (Zeleke and Bliss, 2010). Today, the land is intensively used whereby large natural forest cover is virtually absent. The remnants of these original vegetation types are found in small patches only around sacred places and on the steeper slopes of the escarpment, and also along stream courses as riverine trees. Very big and old scattered wild trees observed in agricultural fields, woodlots, front yards, and grazing lands are indicators for the previous vegetation cover that consisted of various indigenous and endemic plant species. The portion of land under forest is very small and even here only a few stands of indigenous trees such as *Cordia Africana*, *Croton Macrostachyus* and *Podocarpus* *falcatus* are observed. Trees and shrubs are sparsely covering the largest part of the watershed. Exotic trees, specifically *eucalyptus species* are planted extensively around settlements and along river courses. The LU in the watershed is based on mixed rain-fed agriculture. More specifically, it is *enset*-coffee-livestock system that combines annual and perennial crops with livestock production (Le Gal and Molinier, 2006).

b) Image Pre-processing

LC changes in the study area for over 26 years period were extracted from digital satellite imageries of Landsat Thematic Mapper (TM,1984), and Landsat Enhanced Thematic Mapper Plus (ETM+, 2000 and 2010). These Multi-temporal Remote Sensing (RS) data were imported to ERDAS (v.10) Imagine software. The imageries were first radiometrically and geometrically corrected and georeferenced with the help of 1:50,000 topographic maps. Image mosaicking, clipping of area of interest (AOI), enhancement and rectification were applied on the images. Accuracy assessment for the LU/LC maps was based on 34-ground truthing points. The ground-truth information required for the classification and accuracy assessment of imageries was collected through the field observations during March - April, 2013 which also helped to rectify GCPs for geo-referencing, visual interpretation of the images and select reference areas. All referenced areas were digitally documented and localized by GPS measurements.

c) Image Transformation and Classification

In order to enhance visual identification, image transformations were applied on each of the FCC images. To aid the discrimination of the different land cover classes Tasseled Cap Transformation (TCT) was applied. The maximum likelihood classifications were applied for the image classification after selecting training areas. Because of powerful classification capacity of the software, ENVI 4.3 (Environment for Visualizing Images) was used for supervised LU/LC classifications and post classification comparison analysis. To increase the accuracy of supervised classification, more than 5,000 pixels were used to create a signature for each LU/LC classes.

d) Post classification / Supervised

After selectively combining classes, classified images were sieved, clumped and filtered before producing final output. Sieving removes isolated classified pixels using blob grouping, while clumping helps maintain spatial coherency by removing unclassified black pixels (speckle or holes) in classified images. Finally, a 3 x 3 median filter was applied to smoothen the classified images. Classified images were then exported to ArcGIS (V.10) from ENVI. The polygons of <0.5 ha in size were eliminated to minimize the effects of classification errors arising from resolution differences among the satellite images while at the same time without significantly altering the area under each LU class. The resultant polygon themes were used in further analyses. The LU polygon themes for the imageries were then overlaid at a time in ArcGIS and the area converted from each of the classes to any of the other class was computed.

Shuttle Radar Topographic Mapping (SRTM) image having 30m resolution and Ethio-GIS database were used to delineate the watershed and produce different maps respectively.

e) Vegetation Stress Detection

Normalized Difference Vegetation Index (NDVI) is one of the most common indices of analysis of density of vegetation cover and has been used in order to measure changes in the density of vegetation cover and land degradation in the watershed. It is preferred to the simple index (EVI-Enhanced Vegetation Index) as it corrects reflectance distortions caused by the particles in the atmosphere as well as the ground cover below the vegetation. In this research, NDVI (Lu *et al.,* 2004) was computed as:

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

Where: NIR: reflectance in the near infrared portion of the electromagnetic spectrum
R: red band value recorded by satellite sensor.

NDVI values range from -1.0 to +1.0. Negative values approaching -1 correspond to water or values close to zero (-0.1 – 0.1) represent no vegetation / bare land, and low positive values correspond to shrub & grass lands. Values close to +1.0 represent luxurious vegetation. In general, the cover density increases as the positive value increases.

IV. Results And Discussion

a) Land use/Land Cover classification

Classification of LU in order to facilitate its analysis is always contentious as it collates consideration of present LU and/or potential LU; that is, the land capability. This study, however, focused on how land is being used at present compared to the use of the same land in the past. With little modification to (FAO, 2004) LC classification legends, five major LU/LC types: forest land, shrubs and grassland, tree plantations, cultivated land and degraded land have been identified in Wallecha watershed based on the characteristics of Landsat imageries and repetitive results obtained with the help of ground surveys (Table 1).

As the LU/LC classification from 1984 landsat4 TM image is presented in *Table 1*, the greatest share of LU/LC from all classes is cultivated land covering about 37.36 percent of the total area, followed by exotic tree plantations, and forest and wetlands covers (*Figure 2a*).

As shown in *Table 1*, in the year 2000, the coverage of cultivated land and exotic tree plantations markedly increased than it was in 1984. However, the remaining LU/LC types: forest lands, shrubs and grass lands, and degraded lands found decreased in their areal coverage (*Figure 2b*).

Table 1: Areas of LU/LC Classes of Wallecha Watershed for Study Period

LU/LC Class	1984		2000		2010	
	Ha	%	ha	%	ha	%
Forests and Wetlands	2153.34	21.29	1405.26	13.89	1262.16	12.48
Shrubs and Grasslands	1134.36	11.21	1082.43	10.70	728.10	7.20
Tree Plantations	2561.22	25.32	3030.57	29.96	3343.14	33.05
Cultivated land	3779.91	37.36	4271.85	42.23	4493.79	44.42
Degraded land	487.89	4.82	326.61	3.23	289.53	2.86
Total	10116.70	100.00	10116.70	100.00	10116.70	100.00

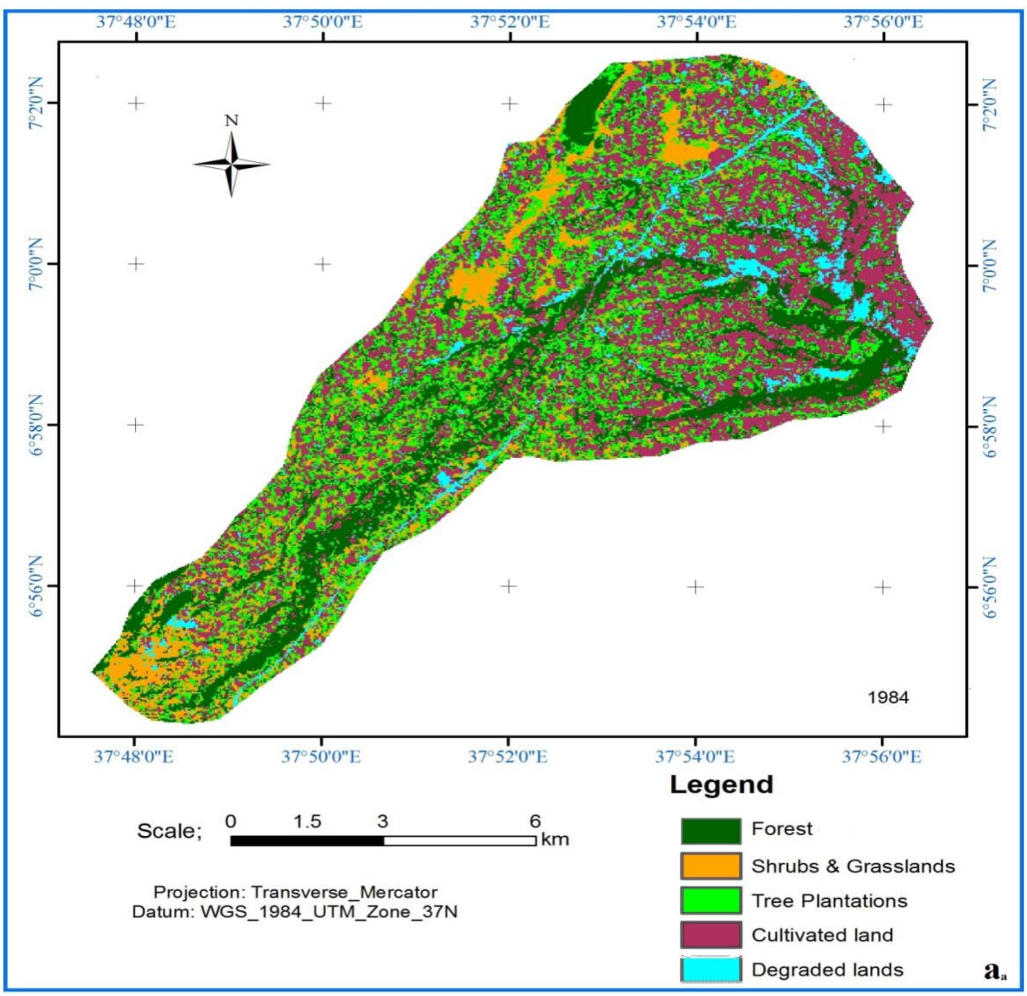

Figure 2a: LU/LC Map of 1984

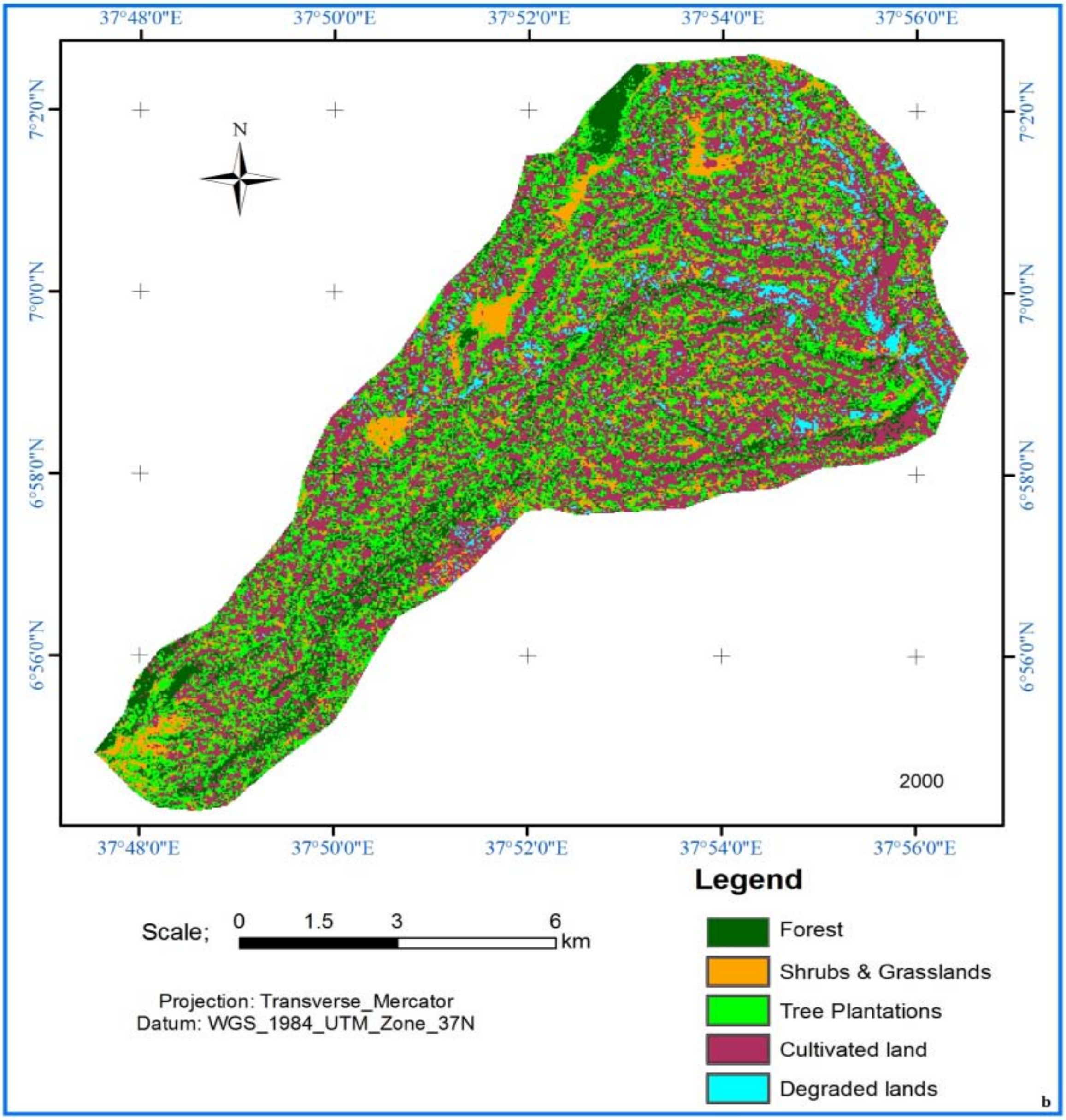

Figure 2b: LU/LC Map of 2000

In the year 2010, cultivated land took the highest share covering 44.42 percent of the total watershed area, followed by tree plantations. Only 12.47 percent and 7.2 percent from the total coverage was by forests and shrub & grass lands respectively while the least areal extent covered by degraded land *(Figure 2c)*.

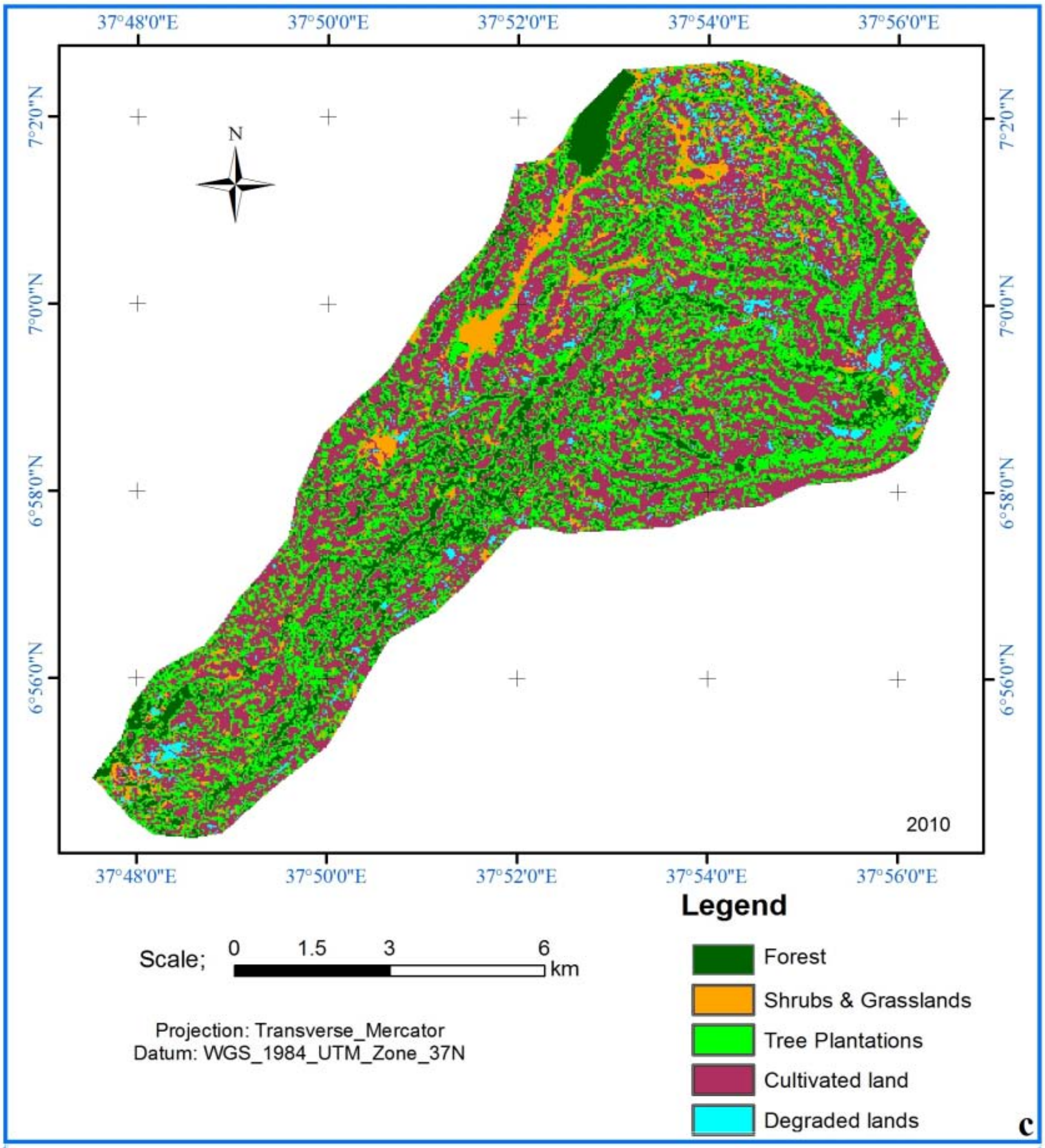

Figure 2c: LU/LC Map of 2010

b) The Extent of LU/LC Change in the Watershed

An important aspect of change detection is to determine which land use class was actually changed to what another LU/LC type. This process involves a pixel to pixel comparison of the study period images through overlay analysis. The LU/LC change matrices presented in *Table 2, 3* and *4* depict the direction of change and the land use type that remained unchanged (*Figure 3*).

It is found that of the total area of forest and woodlands, shrub and grass lands, and tree plantation in 1984, only about 33, 31 and 39 percent of areas respectively were found unchanged in 2000. Whereas, the rest great portions of these LU/LC areas were converted to other types *(Table 2)*. As to the area of degraded lands, only about 27 percent remained unchanged between 1984 and 2000. However, much (62.94%) of the cultivated land areas were not consumed by other LU/LC types between 1984 and 2000. It can also be seen from *Table 2* that, while larger portions of forest and woodlands, shrub and grass lands, and cultivated lands converted to tree plantations, portion of degraded areas were converted to cultivated lands between 1984 and 2000.

The conversion of forest and woodlands, shrub and grass lands to cultivated land is mainly associated with the land demand for crop production to satisfy the food demand of increasing human population, and loss of land productivity in relation to unsustainably managed crop cultivation approach. As a result of land degradation, i.e., the land with gullies and outcrops of stones due to runoff, it is common practice to plant tree species, dominantly *Eucalyptus saligna* and *Cupressus lusitanica Gravellia robusta* in the area.

Table 2: LU/LC Conversion Matrix between 1984 and 2000

			LU/LC Class in 2000					
	LU/LC classes		Forests	Shrubs & grass lands	Tree Plantations	Cultivated lands	Degraded lands	Total
Le/LC Class in 1984	Forests	ha	*711.00*	98.91	737.82	598.41	7.20	2153.34
		%	*33.02*	4.59	34.26	27.79	0.33	100.00
	Shrub & grass lands	ha	124.02	*351.36*	467.55	187.47	3.96	1134.36
		%	10.93	*30.97*	41.22	16.53	0.35	100.00
	Tree Plantations	ha	356.49	301.59	*1004.04*	871.02	28.08	2561.22
		%	13.92	11.78	*39.20*	34.01	1.10	100.00
	Cultivated lands	ha	199.08	275.04	772.11	*2378.9*	154.8	3779.91
		%	5.27	7.28	20.43	*62.94*	4.10	100.00
	Degraded lands	ha	14.67	55.53	49.05	236.07	*132.57*	487.89
		%	3.01	11.38	10.05	48.39	*27.17*	100.00
	Total	ha	1405.30	1082.43	3030.57	4271.9	326.61	10116.72
		%	13.89	10.70	29.96	42.23	3.23	100.00

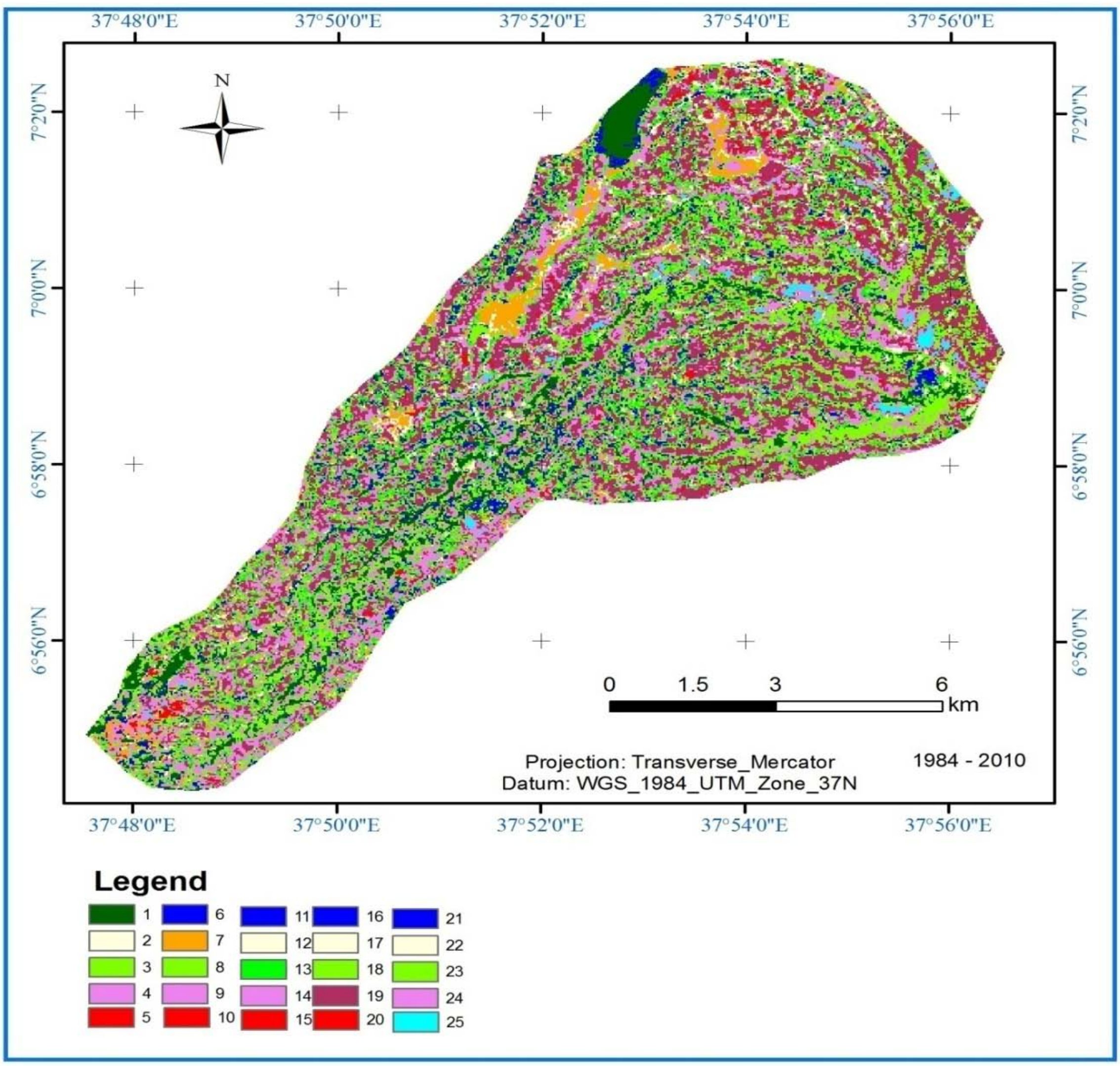

Figure 3: LU/LC Change Map between 1984 and 2010

Table 3: Description for legend colors of LU/LC Change Map

1. Forest to Forest	6. Shrub & grass to Forest	11. Tree Plantations to Forest	16. Cultivated lands to Forest	21. Degraded lands to Forest
2. Forest to Shrub & grass	7. Shrub & grass to Shrub & grass	12. Tree Plantations to Shrub & grass	17. Cultivated lands to Shrub & grass	22. Degraded lands to Shrub & grass
3. Forest to Tree Plantations	8. Shrub & grass to Tree Plantations	13. Tree Plantation to Tree Plantations	18. Cultivated lands to Tree Plantations	23. Degraded lands to Tree Plantations
4. Forest to Cultivated lands	9. Shrub & grass to Cultivated lands	14. Tree Plantations to Cultivated lands	19. Cultivated lands to Cultivated lands	24. Degraded lands to Cultivated lands
5. Forest to Degraded lands	10. Shrub & grass to Degraded lands	15. Tree Plantations to Degraded lands	20. Cultivated lands to Degraded lands	25. Degraded lands to Degraded lands

As to LU/LC conversion between 2000 and 2010, small portion of forests, shrub & grass lands, tree plantations and degraded lands was remained unchanged *(Table 4)*. As to the converted LU/LC size in the period, larger areas of forests and cultivated lands were converted to tree plantations, and more of shrub & grass lands and degraded lands were converted to cultivated lands.

Table 4: LU/LC Conversion Matrix between 2000 and 2010

	LU/LC class		LU/LC Class in 2010: Forests	Shrubs & grass lands	Tree Plantations	Cultivated lands	Degraded lands	Total
LU/LC Class in 2000	Forests	ha	*470.07*	55.17	588.24	283.23	8.55	1405.26
		%	*33.45*	3.93	41.86	20.15	0.61	100.00
	Shrub & grass lands	ha	81.54	*266.04*	340.74	351.09	43.02	1082.43
		%	7.53	*24.58*	31.48	32.44	3.97	100.00
	Tree Plantations	ha	496.53	253.35	*1257.48*	989.19	34.02	3030.57
		%	16.38	8.36	*41.49*	32.64	1.12	100.00
	Cultivated lands	ha	208.62	143.37	1118.34	*2668.41*	133.11	4271.85
		%	4.88	3.36	26.18	*62.46*	3.12	100.00
	Degraded lands	ha	5.4	10.17	38.34	201.87	*70.83*	326.61
		%	1.65	3.11	11.74	61.81	*21.69*	100.00
	Total	ha	1262.16	728.1	3343.14	4493.79	289.53	10116.72
		%	12.48	7.20	33.05	44.42	2.86	100.00

Table 5 shows that of the total forest and wetlands area in 1984, only about 637.38ha (30%) remained unchanged in 2010. The rest forest area was converted to other LU/LC types as shown in the *Table 4.* In contrast, conversion of other LU/LC types to forests amounted only 29 percent compared with 70 percent that was lost to other LU/LC types.

Furthermore, only about 302.94 ha (26.7%) of shrub-grasslands in 1984 was still under the same cover condition in 2010, and the rest 831 ha (73.3%) of shrub-grasslands were transformed to other LU/LC types. The area of shrub-grasslands that changed from other LU/LC types in 2010 was comparatively small accounting only about 58.4 percent. As to exotic tree plantations, about 59.26 percent of the 1984 area was found converted to other LU/LC types in 2010.

Of the total cultivated area in 1984, about 34.5 percent converted to other LU/LC types until 2010. On the other hand, about 44.91 percent of the cultivated area in 2010 was converted from other LU/LC types. It is worth mentioning here that about 64.87 percent of the degraded lands in 2010 was due to the conversion of other LU/LC types. Thus, it is apparent that the forest land and shrubs and grass land LU/LCs were most at risk of undergoing change.

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In general, the natural forest lands were highly disturbed and the resource base has been damaged. Basically the leading reason for this conversion is demand of cultivation land. Rather than improving the productivity of the land under use with integrated land use system, clearing the natural vegetation and converting to crop cultivation, and later in to tree plantation with exotic tree species, and recently with different fruit trees.

Table 5: LU/LC Conversion Matrix between 1984 and 2010

	LULC class		LU/LC Class in 2010 Forests	Shrubs & grass lands	Tree Plantations	Cultivated lands	Degraded lands	Total
LU/LC Class in 1984	Forests	Ha	*637.38*	63.9	933.21	508.23	10.62	2153.34
		%	*29.60*	*2.97*	43.34	23.60	0.49	100.00
	Shrub & grass lands	Ha	127.17	*302.94*	374.76	295.65	33.84	1134.36
		%	11.21	26.71	33.04	26.06	2.98	100.00
	Tree Plantations	Ha	346.95	190.44	*1043.37*	952.11	28.35	2561.22
		%	13.55	7.44	*40.74*	37.17	1.11	100.00
	Cultivated lands	Ha	138.06	139.95	911.07	*2475.81*	115.02	3779.91
		%	3.65	3.70	24.10	*65.50*	3.04	100.00
	Degraded lands	Ha	12.60	30.87	80.73	261.99	*101.7*	487.89
		%	2.58	6.33	16.55	53.70	*20.84*	100.00
	Total	Ha	1262.16	728.1	3343.14	4493.79	289.53	10116.72
		%	12.48	7.20	33.05	44.42	2.86	100.00

c) *Rate of LU/LC Change in the Study Watershed*

The results of image processing for the rate of LU/LC changes between 1984 and 2000 have been presented in *Table 6* and indicated that cultivated land and tree plantation increased with a rate of 30.75 and 29.33 ha/year respectively consuming areas largely from forest lands, and shrub & grassland *(Table 6)*. On the other hand, forest lands dramatically reduced at the mean annual rate of 46.76ha implying the fact of largely agricultural expansion. Shrubs and grasslands also reduced at rate of 3.25 ha/year. Whereas, the degraded lands decreased by 10.08 ha/year mainly due to massive afforestation and preservation of common tree species such as Eucalyptus and pine through campaign programs by then regime.

Table 6: Pattern of LU/LC change between 1984 and 2000 in Wallecha watershed

LU/LC Classes	Change from 1984 to 2000 Ha	%	Mean Annual Rate of Change ha	%
Forests	-748.08	-34.74	-46.76	-2.17
Shrubs and grasslands	-51.93	-4.58	-3.25	-0.29
Tree plantations	469.35	18.33	29.33	1.15
Cultivated land	491.94	13.01	30.75	0.81
Degraded land	-161.28	-33.16	-10.08	-2.07

In the period between 2000 and 2010, exotic tree plantations increased with a mean annual rate of 31.25 ha/year, followed by 22.19 ha/year increase in cultivated lands *(Table 7)*. The reduction in forest lands and shrub & grassland was also experienced at the rate of 14.31 and 34.43 ha/year respectively. However, degraded lands slightly decreased at the rate of 3.71 ha/year.

Table 7: Pattern of LU/LC Changes between 2000 and 2010 in Wallecha Watershed

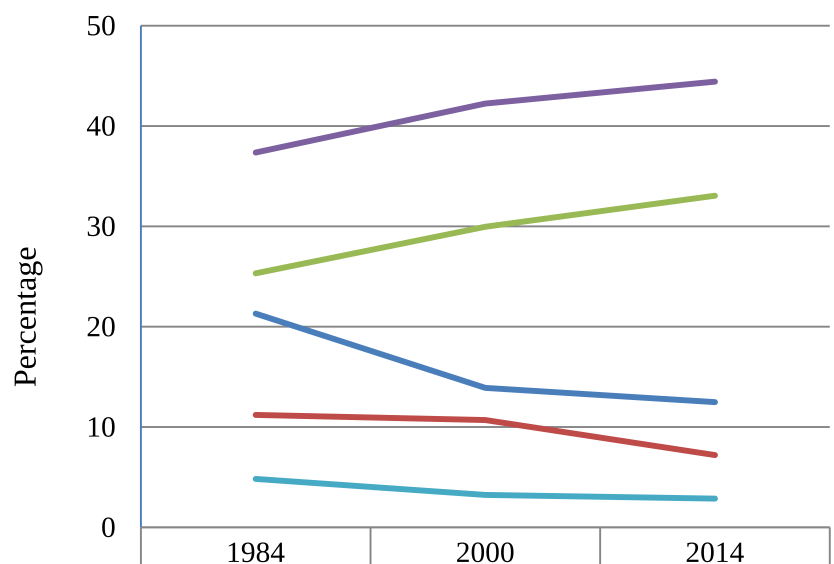
LU/LC Classes	Change from 2000 to 2010 Ha	%	Mean Annual Rate of Change ha	%
Forests	-143.10	-10.22	-14.31	-1.02
Shrubs and grasslands	-354.33	-32.62	-35.4	-3.27
Tree plantations	312.57	10.31	31.25	1.03
Cultivated land	221.94	5.2	22.19	0.52
Degraded land	-37.08	-11.45	-3.71	-1.14

Between 1984 and 2010, tree plantation and cultivated land still continued to increase with the mean annual rate of 30.07 and 27.45 ha/year respectively *(Table 8)*. The reduction in forests and shrubs and grassland also continued with more or less similar pattern; i.e. with about -1.59 and -1.35 percent per annum. Whereas, reduction in degraded land increased as compared to previous years with the rate of -7 ha/year. Degraded lands were transformed to other land LU/LCs mainly as the case of government interventions and community initiatives to rehabilitate bare lands in the watershed in the period.

In general, the pattern showed a tendency towards more land being brought under cultivated land, while tree plantations became more important at the expense of shrub-grassland and riverine trees.

Table 8: Pattern of LU/LC Changes between 1984 and 2010 in Wallecha watershed

LU/L C Classes	Change from 1984 to 2010		Mean Annual Rate of Change	
	Ha	%	ha	%
Forests	-891.18	-41.39	-34.27	-1.59
Shrubs and grassland	-406.26	-35.81	-15.63	-1.38
Tree plantations	781.92	30.53	30.07	1.17
Cultivated land	713.88	18.89	27.46	0.73
Degraded land	-198.36	-40.66	-7.63	-1.56



	1984	2000	2014
Forests and Wetlands	21.29	13.89	12.48
Shrubs and Grasslands	11.21	10.70	7.20
Tree Plantations	25.32	29.96	33.05
Cultivated land	37.36	42.23	44.42
Degraded land	4.82	3.23	2.86

Figure 4: Pattern of LU/LC Changes between 2000 and 2010 in Wallecha Watershed

d) The State of Vegetation Cover Density

On the basis of the NDVI values drawn through the analysis of spectral reflectance of the red and the near infrared bands for the imageries, three state of vegetation disturbance levels (Highly, Moderately and Less stressed) have been estimated for the watershed and the classes were identified based on the class identification and labeling process to generate time-series class signatures involving secondary data to resolve mixed classes *(Table 9)*.

Table 9: NDVI based Estimation of Land Degradation Levels

No.	NDVI Value	Land Use/Land Cover type	Estimated Stress level
1	$\leq$ 0.15	Degraded lands and Settlement areas, parts of intensively cultivated lands	Highly Stressed
2	0.15 – 0.3	Shrubs and grassland, cultivated lands, parts of natural vegetation	Moderately Stressed
3	> 0.3	Natural forests, Plantations and healthy vegetation's	Less Stressed

The NDVI values of the different cover types for the year 1984, 2000 and 2010 imageries clearly show highest value for vegetation cover as 0.71, 0.58 and 0.60 respectively with the mean value 0.31, 0.13 and 0.27 for the year 1984, 2000 and 2010 respectively. The lowest cover values have also been measured as -0.09, -0.31 and -0.07 for 1984, 2000 and 2010 respectively. These indicate that the state of the vegetation cover was better during the 1980s and poor around 2000 and getting improved during 2010. Thus, the final watershed disturbance maps generated for the Wallecha watershed have revealed that 2420.9 ha (23.9 %), 4273.23 ha (42.2 %), and 3422.58 ha (33.8%) of the watershed area falls within highly, moderately and less stressed respectively in the year 1984 (Figure 5a). For the year 2000, the values for highly stressed class became 4908.96 ha (48.5%), moderately stressed became 3852.8 ha (38%) and the remaining 1354.96 ha (13.39%) was less stressed (Figure 5b). In the year 2010, 2644.33 ha (26%), 6196.34 ha (61%) and 1276 (13%) of the watershed were found highly, moderately and less stressed respectively (Figure 5c).

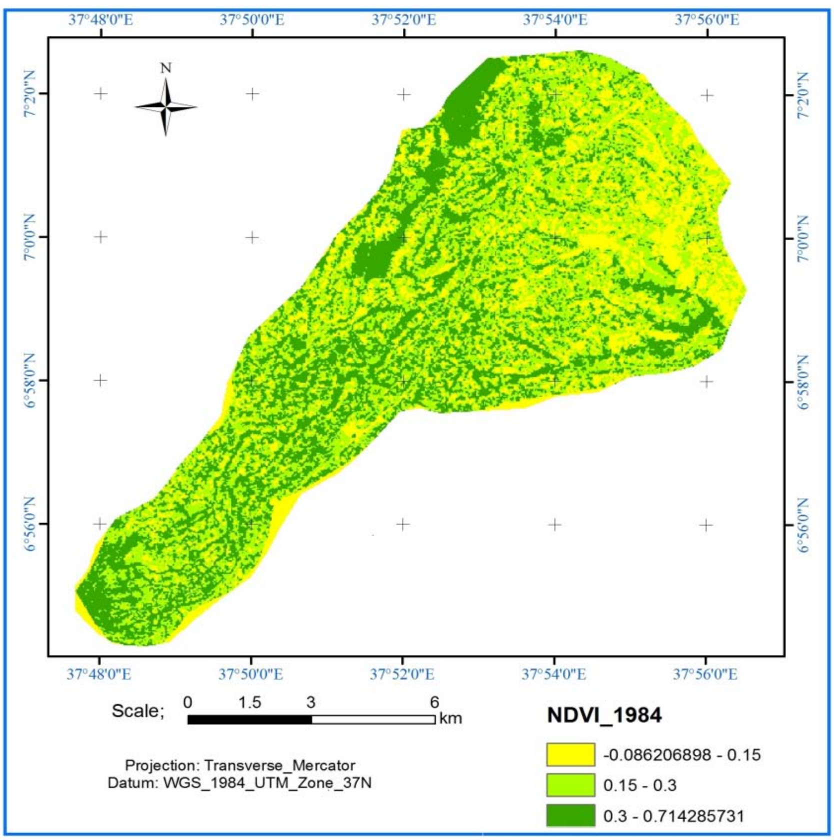


Figure 5a: NDVI map of the Wallecha Watershed for 1984

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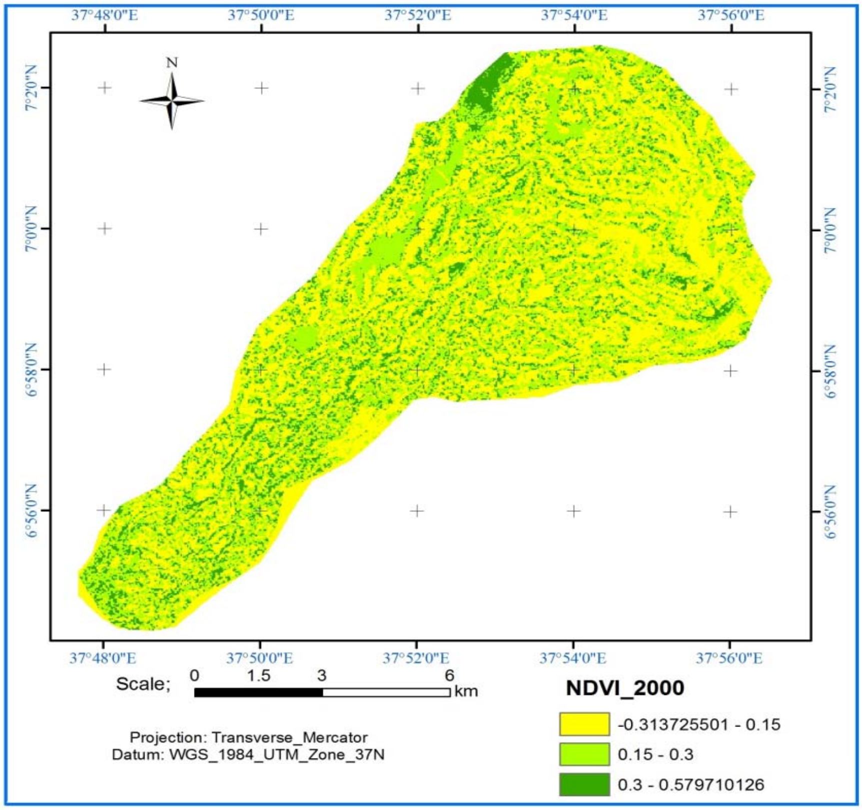

Figure 5b: NDVI map of the Wallecha Watershed for 2000

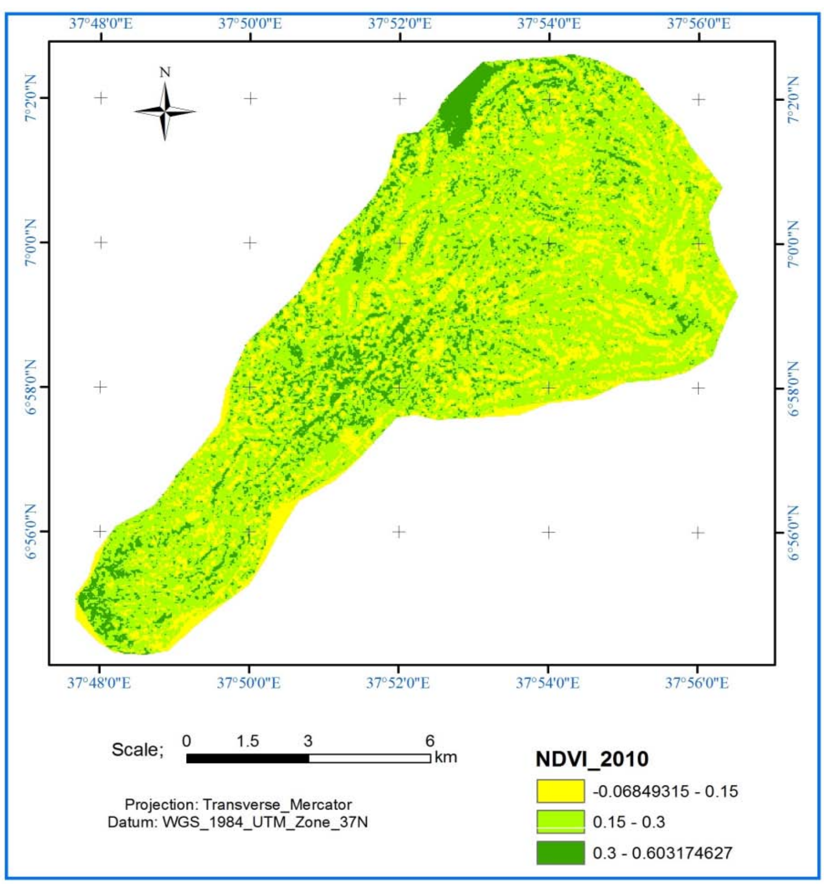

Figure 5c: NDVI map of the Wallecha Watershed for 2010

V. Conclusion

The observed LU/LC changes and associated problems in Wallecha Watershed has sustainable land management and environmental implications. The LU/LC changes occurred in the study area either degraded or enhanced the land's capacity for sustained use and regaining its natural cover. The removal of vegetation cover in the landscape by implication increased the risk of soil erosion. Before 1984, the current cover types (short grasses and remnant bamboo forest) were occupied by highland forests, bush; suggesting substantial rate of forest degradation in the watershed. Generally, the increasing dynamics of LU/LC leads to an increase in the vulnerability of the landscape (reduction in vegetation cover, soil degradation and the depletion of biodiversity, which in turn leads to environmental deterioration) although there is some positive impacts from tree plantations. Choices of the land users are influenced by driving forces: a web of economic, social and bio physical factors that frame their livelihood patterns. Therefore, scale up of sustainable land management practices through adaptive management can only be achieved if concerned farmers and other direct stakeholders *perceive SLM to be in their own best* interest (i.e. adoption of improved systems and practices provides a tangible return for their efforts and investment within a reasonable time frame. Hence, greater emphasis must be given to wise use and SLM practices, and integrated environmental rehabilitation programs have to be implemented.

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