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Original Research

Remote Sensing GIS Based Spatio-temporal Land Use/ Cover Study of Western Ethiopian Highlands –A Case of Jima Arjo District

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Abstract

This paper was aimed at studying the spatio-temporal dynamics of land use/cover over western Ethiopian highlands in the period 1973 to 2006 years (for 33 years) and its future trend. In order to analyze the status of dynamics, the whole study period was categorized in to three periods; 1973-1986, 1986-2001 and 2001-2006. Four different time landsat satellite images (1973, 1986, 2001 and 2006) were obtained and classified into the existing seven major land use/cover types (farmland, dense forestland, degraded forestland, open woodland, grassland, wetland and bare land) using remote sensing-GIS technology. From post-classification change detection among the image data, Jima Arjo district experienced various levels of land use/cover dynamics. Much of the area has been converted in to farmland (*170.54 sq. km)* with an average expansion of 5.168 sq.km per year. Maximum rate of farmland expansion was recorded during the 1986 to 2001 years period were *151.715* sq. km of the area became farmland. Vegetations showed loss and gain changes. Forested areas were diminished greatly due to their conversion to other forms of land use/cover across the whole period. Much of the original dense forests (171.16 sq. km of the area) were lost with 5.186 sq.km average annual loss. Extreme forest loss was recorded during the 1973 to 1986 years period were 112.6 sq. km has been lost. Wetlands were also showed reduction in extent. Of the original 84.52 sq.km wetland, only 0.84 sq.km has been identified at the final study period. Analysis of the land use/cover distribution across various slope categories also showed that steep slopes were made farmlands. On the latest image, 7.3814 sq. km area of slope with more than 25^0 and 30.0892 sq. km area with slope range of 12^0 to 25^0 were converted in to farmlands. Vulnerability to change has been modeled and predicted based on the latest land use/cover data. Four levels of vulnerability to change: extremely vulnerable, highly vulnerable, moderately and low vulnerable to change were identified. Vegetations, particularly degraded forest shared 65.2% of extremely high vulnerability level to change. Almost all the remaining dense forestland became extremely and highly vulnerable to change/transformation.

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INTRODUCTION

Land use and land cover are not equivalent but they are connected and function as hybrids. While land use is the human employment of the land, land cover indicates the physical state of land. The change of human use of land is associated with change in the physical states of land cover. Although land use/cover change are caused by both natural and anthropogenic factors, most land use/cover changes and dynamics are attributed to the interaction between human continued demand for land products and the capacity of the land and the environment to sustain the demand (Meyer and Turner, 1998).

Many research studies indicated that land use/cover dynamism is primarily associated with agricultural activity. Wright (1993), Botkin and Keller (2005) described that agriculture and settlements are the major ways in which people have changed the natural landscape. Three most important human factors were recognized as change agents of land use/cover. The first is the need to provide food for rapidly growing population. This necessitates the expansion and intensification of agricultural land. The second is the provision of land for the landless in order of self sufficiency to exist and the third is to provide land for multinational companies to carry out agribusinesses.

Ethiopia is an agrarian country where agriculture provides a livelihood for over 90% of its population (Ministry of Agriculture & Rural Development, et al., 2005). At the inception of agriculture, most of the land cover of the country was believed to have been forest and at the turn of 20^{th} century, 40% of the country's land surface had been covered with forest. Since then, forest clearance was started in favor of crop production (Solomon Abate, 1994). With the rapid growing population of the country, the event yet calls for more forest clearance for further farm expansion, grazing and extraction of forest and forest products (Krauer, 1988).

The highlands of the country are favorable for human habitat and they are the most significant economic areas. But they have signified rugged topography dissected by deep gorges with slopes associated with diverse climate (Hurni, 1986). Such physiographic features require careful agro-ecologically sustainable management (World Bank, 2006).

South western high-lands of Ethiopia; were the study was conducted/Jima Arjo district/, was relatively settled recently, less densely populated and believed to have good vegetation cover (Solomon Abate, 1994). However, the severity and rate of loss of natural vegetation in the region currently is indeed alarming. This can be realized from the work of Taffa Tulu (2002) in that the forest resources of Ethiopia are concentrated on 3% of the area mainly located in the south western highlands.

Proper organization and monitoring of land resources requires not only an understanding of the spatial and temporal patterns of resources but also insight in to the spatial and temporal process governing their availability. Such analysis demand timely repetitive and continuous spatial data. Remote sensing and GIS technique has proven capacity in assessing and monitoring the land resource.GIS, using multi criteria analytical facilities can integrate multi-criterion comparison techniques so as to predict geographical related problems (Eastman, 2006).

Towards this a study has been conducted to assess the status and trend of land use/cover. The study delineated change and degradation vulnerable areas in the district using remote sensing and GIS technology.

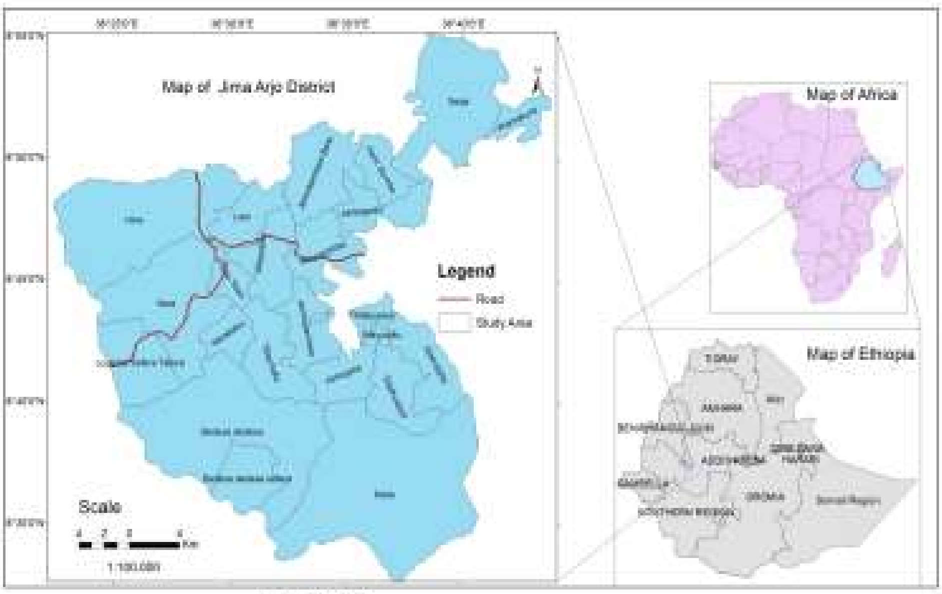
MATERIALS AND METHODS

Background of the Study Area

Location and Physiography

Jima Arjo is found in East Wollega Zone of Oromia region right at 379Km West of Addis Ababa. The district is located in between $8^0$33' to $8^0$55'N latitudes and $36^0$22' to $36^0$44'E longitudes (figure 1).

The physical landscape of Jima Arjo is quite diversified. The major topographic features of the area are composed of hilly, flat to undulating rugged topography, plain, plateau and valley with altitude variation from 1264 at Didessa valley floor in the south west to 2599 m a.s.l. at Hine ridge in the North western part of the area.



Source: CSA, 2008

Figure 1: Map of the study area

Climate:

According to the agro-climatic classification of Ethiopia by Ministry of Agriculture, Rurl Development of Ethiopia, Regional Land Management and World Agro forestry Center (2005), 30% of the area has lowlands with an elevation of <1500m a.s.l, 58% of it has mid altitude with elevation between 1500 – 2300m a.s.l and 12% of it is highland having elevation >2300m a.s.l.

The mean rainfall based on 19 years record (1988-2006) is 1855.3 mm. Even though the intensity of rain varies, almost all months receive rainfall. April-September are months with high rainfall and over 76% of the area receives maximum rain from May to September. The lowest mean monthly rainfall (14.1mm) was recorded in the month of January while the highest 332mm recorded in August.

The recorded temperature of the study area ranges from10^0C to 23^0C with average annual temperature of ~16^0C. The hottest and coldest months are March and July, respectively.

Description of Data Used

The study requires ground surveying of land resources data which is often expensive. Such data analysis also demands timely repetitive and continuous spatial data (Wall *et al*., 1982). Remote sensing and GIS technology has proven capability in acquiring and processing such data. LandSat satellite remote sensing employing multispectral scanning systems provide data for the identification of land cover at different times on a continual basis (Lillesand and Kiefer, 2000).

Remotely sensed LandSat satellite image data of four periods (1973, 1986, 2001 and 2006 years) (table 1), Global digital elevation (SRTM) data, shape file data, digital soil data and toposheets were used for the study. Climate data (RF and Temp) and surveyed field data were also employed for the study.

Table 1: Summary of satellites image data used for the study

Image	Path/Row	Acquisition Year	Source
Landsat MSS	182/054	1973	GLCF online portal
Landsat TM	170/054	1986	GLCF online portal
Landsat ETM+	170/054	2001	GLCF online portal
Landsat ETM+	170/054	2006	GLCF online portal

MSS = Multi Spectral Scanner, TM = Thematic Mapper; ETM+= Enhanced Thematic Mapper Plus

Methodology Description

GIS analysis techniques were used for the study. Digital LandSat satellite images were extracted and enhanced using radiometric and spectral enhancement techniques, RGB to IHS conversions and color combination of the original image so as to make the image visually interpretable and identify features in the image data. The image data has been analyzed and classified in to different land covers using both ERDAS 2010 and ENVI 4.7 software. The classified data were further analyzed for change detection. Terrain data (elevation and slope) generated from SRTM data were processed after patching for the anomalies using 3DEM visual software and further processed using ArcGIS 10.2 software spatial analyst tools. Change susceptibility factors were generated from secondary topomaps through digitization in the ArcMap ArcGIS.

GIS multicriteria analysis techniques and vulnerability analysis through pair-wise comparison has been employed using IDRISI Selva version 17 software. The parameters were weighted and overlay analysis has been implemented in the ArcGIS 10.2 environment (Figure 2).

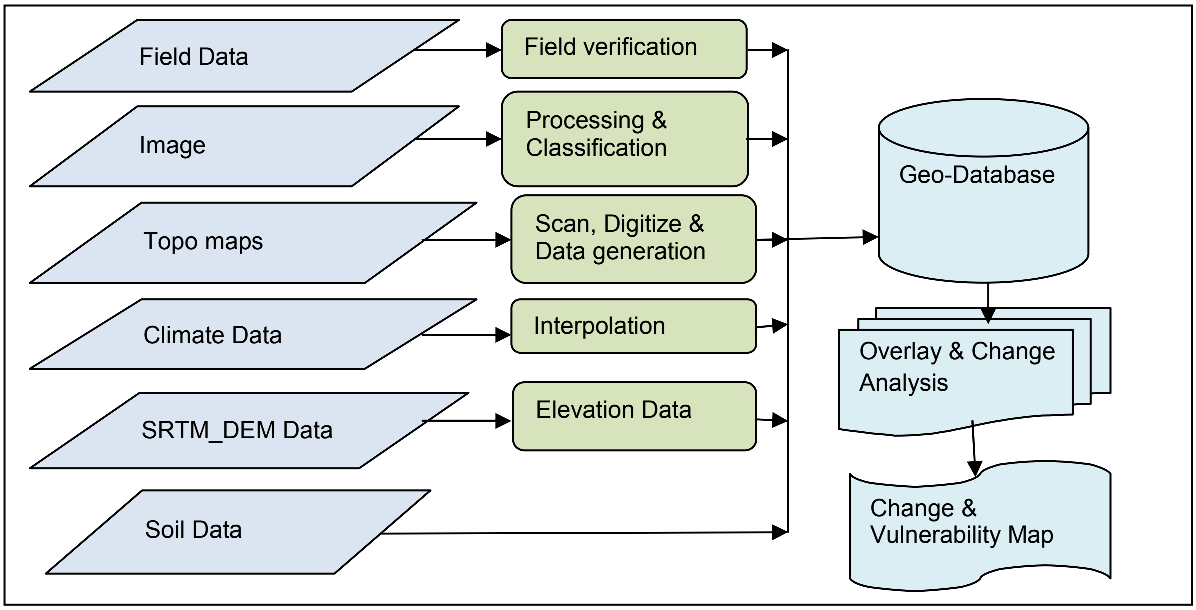


Figure 2: Methodology of the Study

RESULTS AND DESCUSSION

Satellite Image Processing

Orthorectification and/or Restoration of the Images

Image rectification and restoration, which normally precedes any further manipulation (Mather M. Paul, 2004) has been implemented for correcting the distortions introduced to the image data during the acquisition process. The image of the 1986 TM has found with cloud cover since the images were recorded during the summer month over the area. Therefore, some haze compensation techniques were employed on the image. In addition to this, reprojections to Clarke 1880/UTM zone 37N were made to all the images since the national map products of Ethiopia use this projection (Bedru Sherefa, 2006).

Image Enhancement and Visual Interpretation

To aid the visual interpretability and identification of major land use/land cover types of the images histogram equalizer and tasseled cap transformation were employed to the image data. RGB to IHS conversions and color combination of the original image data have also been made. The Vegetation index, NDVI, has also been used to measure the presence and state of vegetation so as to distinguish vegetated areas from others. It was computed from the spectral radiance in red(R) and near-infrared (NIR) bands (Eq. 1). The value ranges from -1 to 1, and the highest the value, the proportion of green vegetation in a pixel would be the highest and the lowest negative values are characteristics of either water or bare land (Lillesand *et al.*, 2004). A common range for green vegetation falls between ≈0.2 to 0.8 (ITT, 2006).

$$NDVI = \frac{NIR - R}{NIR + R} \quad \text{------------ Equation (1)}$$

Different NDVI values were produced following the transformation using the equation. The MSS image recorded NDVI values range from about - 0.5 to 0.6, the TM between -0.81 – 0.65 and that of ETM^+ falls between -0.9 and 0.64. These values indicate the state of green vegetation in that the higher the value the higher the amount of healthy green vegetation over the area.

Image Classification and Accuracy Assessment

The four time period images of the study area were first classified through computer automated unsupervised method in ERDAS IMAGINE 2010 classifier. The image data were classified through supervised technique by combining enhanced visually interpretable data, field (GPS) data, spectral profile and the unsupervised classification. Accordingly, 7(seven) major land use/land covers classes namely: farm land, dense forest, degraded forest, open woodland, grassland; wetland and bare land were identified from the images (Figure 3).

After classification the accuracy of the classified data has been assessed using a confusion matrix. Accordingly, the classified image data of 2006 has an overall accuracy of 85% with kappa statistics of 0.72, which is acceptable (Mather M. Paul, 2004).

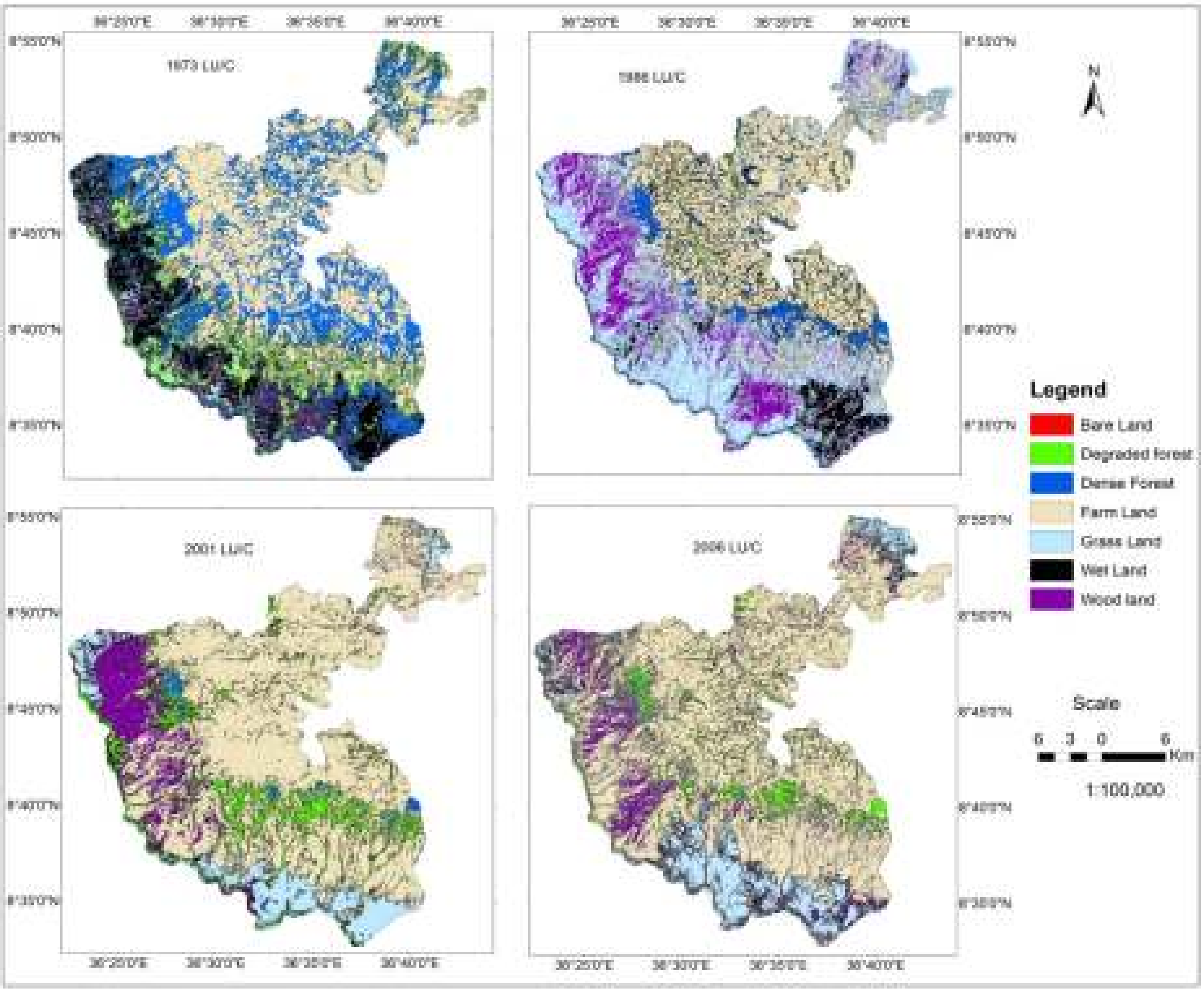


Figure 3: Land use/land cover map of Jima Arjo at different years

Land Use/ Land Cover Change Assessment

In the study area, the temporal and areal dynamics of various land use/land cover categories across 1973 – 2006 have been analyzed. Analyzing the change at different times, help in determining the causal factors, the level of the change and the respective management techniques. For this purpose, the whole time range has been segmented into three periods (1973 – 1986, 1986 – 2001 and 2001 - 2006) and finally the overall change (1973 – 2006) has been assessed.

LU/LC Change between 1973 to 1986

Between 1973 and 1986 (table 2), open wood land and dense forest land showed maximum changes; while the first one increased with 140.12km^2 (10.77 km^2/yr mean rate); the later one decreased with 112.6 km^2 (8.66 km^2/yr). Degraded forest and grassland also showed significant changes in that the earlier one has decreased with 85.02 km^2 (6.34 km^2/yr) but the later one has expanded with *76.59* km^2 (with rate of 5.89 km^2 /yr). Wet land has also reduced with 27.17 km^2 but bare land showed some degree of expansion. Agricultural land in this period showed some expansion (1.55 km^2) and the rate of expansion over the period has been estimated as 0.1km^2/yr.

The data of the change detection matrix (table 3) clearly indicates the trend of each land category in this period. Farm land which was the largest land category (over 43%) over the period has not shown significant change owing to loose and gain of an area. While it gained 69.55 km^2 areas mostly from dense forest (48.94Km^2); it lost 67.06km^2 area to other land category (mainly to open woodland and grassland). Insignificant portion of the farm land (0.28km^2) was converted in to dense forest due to some forest reestablishment.

Table 2: Extent of land use/cover change in 1973 and 1986 years

LU/LC Category	1986		1973		Change (km^2)	Average Rate of Change (km^2)
	Area (km^2)	%	Area (km^2)	%		
Farm Land	338.41	43.8	336.86	43.62	1.55	0.1
Dense Forest	66.797	8.6	179.38	23.2	-112.6	-8.66
Degraded Forest	22.49	2.9	107.51	13.64	-85.02	-6.34
Grass Land	108.25	14.1	31.66	4.113	76.59	5.89
Open Wood Land	175.27	22.7	35.15	4.524	140.12	10.78
Wet Land	57.33	7.4	84.5	10.9	-27.17	-2.09
Bare Land	4.01	0.5	0.3	0.003	3.71	0.3
Total Area	772.5	100	772.5	100		

Table 3: Land use/cover change matrix of 1973 and 1986 years image data

Land Use/Cover Category		Initial State in km^2 (1973)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Wood Land	Wet Land	Bare Land	Class Total
Final State (Km^2) in 1986	Farm Land	267.9	48.94	13.57	1.34	2.25	3.44	0.01	338.4
	Dense Forest	0.28	61.67	3.6	0.2	0.26	0.33	0	66.7
	Degraded Forest	6.56	5.25	10.11	0.04	0.05	0.03	0	22.28
	Grass Land	23.31	7.28	22.15	16.56	12.09	25.6	0	108.2
	Wood Land	30.05	38.54	44.94	10.4	14.83	35.3	0	174.9
	Wet Land	3.06	16.41	9.44	2.92	5.49	19.6	0	57.29
	Bare Land	3.8	0.06	0.13	0	0.01	0	0	4.02
	Class Total	336.86	179.38	104.99	31.66	35.15	84.5	0.01	---
	Class Changes	68.92	117.71	94.88	15.1	20.33	64.9	0	---
	Image Difference	1.6	-112.68	-82.49	76.5	139.77	-27.2	4.01	---

Note: The numbers in the row class total indicate the initial state whereas that of the column indicate the final state of a given land use/ land cover type in Km^2. The Diagonals indicate areas that remained unchanged.

Dense forest, in addition to its conversion to farm land, has been transformed into open woodland and thus has shown significant reduction (about 112.7km^2). Yet, some of the dense forestland at the initial period were abandoned and transformed to grassland and degraded forest land. Of the original 104.99km^2 area of degraded forest land, only 10.11km^2 area has been left unchanged during the final state. Apart from its transformation to farmland, it has been converted to open wood land, grass land and partly to others. Although, the grassland category expanded over the period, some of it has been transformed and gave rise to the revival of some woody trees and others. The open woodland, owing to its less contribution to transformation/conversion but the conversion of others to it, increased in size more than the other categories. Much of the initial state of the wetland has also been converted to open wood land and grass land and hence declined in size at the final period. Comparatively, the bare land though has least areal converge over the period, has increased in extent.

LU/LC Change between 1986 to 2001

This period clearly showed the massive land transformation and magnified the state of human intervention in an ecosystem. With more or less equal time interval with that of 1973 to 1986 period, the amount of farm land during 1986 to 2001, has increased extremely (increased with 151.715 km^2 as compared to *1.55* km^2 in the previous period) with 10.11km^2/yr average rate of change. Large patches of native vegetations have been removed, degraded and either converted or transformed in to farm land. Dense forest has shrunk to the level of inexistence being pushed by the expanding agricultural frontier and other forest product consumption. It constituted only 10.734 km^2 in 2001 (1.4% of the district's total area). Degraded forest area has expanded over the period. The original grass lands, open wood lands and wet lands were drastically diminished. Bare land showed expansion over the period (table 4).

The table of matrix (table 5) shows that farmland (with over 63% coverage), has expanded through out the period due to largely the conversion of the initial open wood land (74.49 Km^2) followed by grass land (47.97Km^2). Farmland also extended to dense forestland (with 32.27km^2). Some of the previously wet lands and degraded forests were also converted to farm lands at the final state of the period. Dense forest was radically diminished more than grassland. It was degraded (16.19 Km^2) and transformed to open wood land and grass land. The degraded forest land also showed relative increment in size during the period.

Table 4: Extent of land use/cover in 1986 and 2001 years

LU/LC Category	2001		1986		Change (km^2)	Rate of Change (km^2/yr)
	Area (km^2)	%	Area (km^2)	%		
Farm Land	490.126	63.4	338.411	43.8	151.715	10.11
Dense Forest	10.734	1.4	66.797	8.6	-65.397	-3.74
Degraded Forest	62.344	8.1	22.493	2.9	39.851	2.66
Grass Land	95.586	12.4	108.253	14.1	12.667	-0.84
Open Wood Land	103.403	13.4	175.275	22.7	-71.872	-4.79
Wet Land	2.688	0.3	57.335	7.4	-54.647	-3.64
Bare Land	7.699	1	4.02	0.5	3.679	0.24
Total Area	772.5	100	772.5	100		

Table 1: Land use/cover change matrix of 1986 and 2001 years image data

	Land Use/Land Cover Category	Initial State in Km^2(1986)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Wood Land	Wet Land	Bare Land	Class Total
Final State in Km^2 (2001)	Farm Land	301.21	32.27	7.94	47.97	74.49	23.57	3.49	490.06
	Dense Forest	0	6.08	0.16	0.92	2.62	0.3	0.02	10.73
	Degraded Forest	8.67	16.19	11.98	13.29	9.87	1.2	0.24	62.34
	Grass Land	16.22	2.18	0.29	29.5	27.64	19.3	0.03	95.53
	Open Wood Land	6.59	6.63	0.94	16.31	59.21	11.61	0.08	103.38
	Wet Land	0.28	0.12	0.02	0.75	0.82	0.57	0	2.69
	Bare Land	5.86	0.69	0.17	0.26	0.73	0.08	0.03	7.7
	Class Total	338.4	66.8	22.49	108.25	175.23	57.33	4.02	---
	Class Changes	37.16	60.72	10.51	81.44	116.02	56.75	3.99	---
	Image Difference	151.65	-56.06	39.85	-12.47	-71.85	-54.64	3.68	---

LU/LC Change between 2001 to 2006

This period covers relatively the shortest time range. During the period, farms were still expanding (raised by 17.3 %) at the expense of open woodland and grassland which were diminished with 11.91 and 18.94km^2, respectively. Inaccessible areas that were previously covered with woodland and grasslands seem the next target for conversion. Wet lands were also became irrigable farms in the period. Degraded forest land was increased owing to the removal of the dense forest over the area. Some of the bare lands in the area that seem to rehabilitate were reused for farming (0.02km^2). Degraded trees and grasses were begun to emerge during the final state over some of the bare lands at the initial state (Table 6 and 7).

Table 6: Extent of land use/cover in 1986 and 2001 years

LU/LC Category	2006		2001		Change (km^2)	Rate of Change (km^2/yr)
	Area (km^2)	%	Area (km^2)	%		
Farm Land	507.4	65.7	490.1	63.4	17.3	3.46
Dense Forest	8.19	1.1	10.7	1.4	-2.51	-0.502
Degraded Forest	87.68	11.35	62.34	8.1	25.34	5.068
Grass Land	83.67	10.83	95.58	12.4	-11.91	-2.382
Open Wood Land	84.46	10.9	103.4	13.4	-18.94	-3.788
Wet Land	0.84	0.12	2.688	0.3	-1.848	-0.37
Bare Land	0.23	0.03	7.691	1	-7.461	-1.5
Total Area	772.5	100	772.5	100		

Table 7: Land use/cover change matrix of 2001 and 2006 years image data

	Land Use/Land Cover Category	Initial Status in Sq. Km (2001)							
		Farm Land	Dense Forest	Degraded Forest	Grass Land	Wood Land	Wet Land	Bare Land	Class Total
Final State in Sq. Km(2006) (2006)	Farm Land	456	0.43	5.07	39.9	3.95	2.02	0.1	507.47
	Dense Forest	0	7.01	0.36	0.62	0.06	0.1	0.04	8.19
	Degraded Forest	0.02	0.73	53.76	0.01	32.09	0.02	0.97	87.6
	Grass Land	20.01	0.23	0.06	44.94	15.8	0.14	2.47	83.65
	Woodland	14.01	2.12	2.89	9.96	51.48	0.01	3.92	84.39
	wet Land	0	0.21	0.2	0.03	0	0.4	0	0.84
	Bare Land	0.02	0	0.01	0.07	0.01	0	0.1	0.21
	Class Total	490.1	10.73	62.35	95.53	103.39	2.69	7.6	
	Class Changes	34.06	0.72	8.59	50.59	51.91	2.29	7.5	
	Image Difference	17.41	-2.54	25.25	-11.88	-19	-1.85	-7.39	

LU/LC Change between 1973 to 2006

Considering the overall study period, a remarkable increase in the areal extent of farm land has been evident; from 336.86km^2 (43.6%) in 1973 to 507.4 km^2 (65.7%) in 2006 with 170.54 km^2 variation across 33 years. While grass land and wood land showed relative increment in coverage, other vegetation categories (particularly dense forest) were dropped down and 171.16 km^2 of the original forestland cover now devoid of forest with an average loss of 5.186km^2 per annum. Of the initial above 23% of dense forest cover, only 1.1 % of the area possessed the original forest. Wet land also reduced and almost reached the status of inexistence were only 0.12% of the original 10.93% remained (Table 8).

Table 8: Statistical Summary of land use/land cover from 1973 – 2006

LU/LC Category	2006		1973		Change (Sq.Km)	Rate of Change (Sq.Km/yr)
	Area (Km^2)	%	Area (Km^2)	%		
Farm Land	507.4	65.7	336.86	43.61	170.54	5.168
Dense Forest	8.19	1.1	179.35	23.21	-171.16	-5.186
Degraded Forest	87.68	11.35	104.96	13.6	-17.28	-0.52
Grass Land	83.67	10.8	31.66	4.1	52.01	1.576
Wood Land	84.46	10.9	35.15	4.55	49.31	1.5
Wet Land	0.84	0.12	84.52	10.93	-83.68	-2.54
Bare Land	0.23	0.03	0.01	0.001	0.22	0.01
Total Area	**772.5**	**100**	**772.5**	**100**		

Table 9 showed how much the land use/land cover of the area is dynamic. It clearly indicates the ultimate impact of extreme anthropogenic interventions in accelerating the removal of the original ecosystem over the area. This is evident in that farm land has been increased dramatically; the forestlands and wetlands were declined extremely over the years.

Table 9: Summary of land use/cover change matrix of 1973 and 2001 years image data

	Land Use/Land Cover Category	Initial State Sq. Km (1973)							
		Farm land	Dense Forest	Degraded Forest	Grass land	Wood Land	wet Land	Bare Land	Class Total
Final State in Sq. Km (2006)	Farmland	313.87	65.1	73.89	14.58	8.01	31.99	0	507.4
	Dense Forest	0.16	7.77	0.13	0.01	0.02	0.1	0	8.19
	Degr. Forest	0.86	60.14	24.9	0.59	0.81	0.38	0	87.68
	Grassland	21.35	15.41	0.97	7.06	6.3	32.58	0	83.67
	Woodland	0.45	30.92	4.99	9.4	19.95	18.75	0	84.46
	Wetland	0.01	0.01	0.07	0.01	0.03	0.71	0	0.84
	Bareland	0.16	0	0.01	0.01	0.03	0.01	0.01	0.23
	Class Total	336.86	179.35	104.96	31.66	35.15	84.52	0.01	
	Class Changes	22.99	171.58	80.06	24.6	15.2	83.81	0	
	Image Difference	170.58	-171.2	-17.28	52.01	49.31	-83.68	0.22	

Land Use/Cover Distribution Across Slope

The pattern of land use/cover correlates to a great extent with the slope of a given area. Agriculture is perhaps one of the activities that largely depend on slope especially in areas where rainfall is intense. Expansion of agriculture over steep slopes results in a disastrous effect towards soil resources. Towards this analysis, the slope derived from SRTM data has been reclassified into 4 slope categories (<5^0, 5-12^0, 12-25^0 and above 25^0) and the land use/cover classes of the initial (1973) and the final (2006) images in each slope category has been tabulated in ArcGIS environment for comparison (table 10).

Table 10: Land Class Extent (in km^2) across Each Slope Category at the Initial and Final States

LU/LC Categories	< 5^0		5^0 – 12^0		12^0 - 25^0		> 25^0	
	1973	2006	1973	2006	1973	2006	1973	2006
Farm Land	84.8	158.9	171.7	233.6	74.8	105.9	5.5	8.91
Dense Forest	46.2	0.1	61.9	1.3	64.4	5.7	6.9	0.97
Degraded forest	44.4	22.6	41.9	31.7	17.8	31.8	0.8	1.56
Wood land	23.9	21.1	7.5	33.5	3.8	28	0.2	1.8
Grass Land	22.8	68.5	5.8	8.2	2.9	6.1	0.05	0.78
Wet Land	49.9	0.8	20.1	0	13.8	0	0.65	0
Bare Land	0	0.05	0.008	0.14	0	0.041	0	0
Total Area(km^2)	272.1		308.5		177.8		14.12	
Percentage	35.2		39.9		23		1.8	

It shows that in 1973, though, farmland occupied wider areas (31.2% area), almost all land use/ cover types were evident in the gentler slope with <5^0. In 2006, 58.4% of the slope <5^0 became farmland. It means that the previous un-accessed areas with gentler slope now accessed and transformed in to farmlands. Dense forestland covered 46.2 km^2 of the area at the beginning within this slope category. But only 0.1km^2 has been left in 2006. Degraded forests in this slope range were also reduced by half. In addition, the previous wetlands evident on gentler slope were almost disappeared. On the other hand, grass lands were revived and hence increased in areal extent in 2006.

The slope class moderate to sloppy (5^0 - 12^0) possesses more area of Jima Arjo (39.9%) and it is in this category that farming has its maximum share in coverage and expansion level in both years (1973 and 2006). In this slope range dense forest loss was extreme. More than 60km^2 area of dense forest removed or converted in to farmlands, woodland or others.

Sloppy to steep slope (12^0 – 25^0) areas were still where farmland is dominant. It is in this slope category that forest land is relatively has more concentration in both years though 58.7km^2 faced loss/conversion.

Strongly steep slope (>25^0) covering about 14.12km^2 of the area. Farmland with 5.5km^2 being concentrated at 25^0 at the beginning was extended in areal cover in 2006 to extremely steep slope in the district. Forestland removal/conversion is also evident across this slope.

In general, the data showed that over the fragile steep slopes (>12^0) that should have been kept for either tree crop production or forest land, farming has become dominant. The remaining forest land (both the dense forest and degraded forest) which has been concentrated more in this slope category were likely to be under greater threat.

Land Use/Cover Change Vulnerability Assessment and Mapping

In order to address the state of land use/land cover change and its future trend, the identification of prone areas is of vital importance. In this study the future vulnerable areas to change has been studied through determining the factors of change.

Generation of Land Use/Land Cover Change Factors Data

Land cover change is primarily determined by anthropogenic factors. The more a land cover is suitable and proximity for use, the more susceptible it is to change and degradation. Altitude and slope, accessibility and proximity to settlement and rivers are among the determining factors that can determines land cover change (Wright, 1993; Mannion, 2002 and Eastman J. Ronald *et al.,* 2005). In addition, soil is the other factor that determines land cover change (Mesfin, 1998). Troeh, et al., (1980) also considered land cover types by themselves determine land susceptibility to change.

Accordingly, the study considered the 2006 year land cover type, factors of accessibility, proximity to settlement, proximity to rivers, slope, soil type and agroclimate of the area. The integration of multi factors and criterion were found to be significant (Hey Wood Ian, *et al.,* 2002) and hence achieved through multi-criteria evaluation techniques in GIS.

For the study, the identified factors and criterion of change were weighted and scored based on their contribution. Reclassification of each factor has been made by assigning scale values ranging from 1 – 7 (since the maximum class category is the land use/cover class).

Table 11: Factors of land use/cover change scale values and their associated weight

Factors	Assigned Scale Values							Weight
	7	6	5	4	3	2	1	
Land Cover Type	Forest	Dg. Forest	Woodl	Grassl	Wet Land	Farml	Barel	0.1733
Soil Type	Nitisols	Vertisols	Gleysols	Acrisol	--	--	--	0.0551
Agro-Climate Type	Wet Sub-tropics	Wet Tropics	Wet Temprate	--	--	--	--	0.0559
Slope Range (Degree)	<2	2-5	5-10	10-16	16-25	25-35	>35	0.1947
Dist.All Weather Road(Km)	<2	2 - 5	5 - 8	8 - 12	12 - 16	16 - 22	>22	0.1460
Dis.Dry Weather Road(Km)	<1	1 - 3	3 - 6	6 - 10	10 - 15	15 - 22	>22	0.1127
Distance to Foot Path(Km)	<1	1 - 3	3 - 5	5 - 7	7 - 10	10 - 15	>15	0.0856
Distance to Town (Km)	<3	3 - 6	6 - 10	10 - 15	15 - 21	21 - 27	>27	0.0854
Distance to Rivers (Km)	>9	6 - 9	4 – 6	2 – 4	1 – 2	0.5 - 1	<0.5	0.0912

*Dist.=Distance to, Forest=Dense forestland, Dg. Forest=Degraded forest, Woodl=Open Wood land, Grassl=Grass land, Farml= Farmland, Barel= Bareland

Since weight evaluation for more factors at a time is quite difficult, pairwise comparison method has proven capability in comparing the relative importance of criterion at a time (Eastman J. Ronald, 2002 and Hey Wood Ian *et al.,* 2002). Hence, in identifying vulnerable areas, pairwaise comparison has been made using IDRISI Selva software. Reclassifying the data layers, the weight of each layer factor has been assigned (table 11) and the layer factors were produced (Figure 4).

Based on the assigned weighted values, pair wise comparison has been made among each of the factor layers in the IDRISI Selva version 17 GIS decision support system in identifying vulnerable areas. Weighted overlay has been implemented to the factors (eq. 2) in the ArcGIS 10.2 software spatial analyst raster calculator (Figure 5).

Susceptibility to Change=LU/LC*0.1733+Agro-Climate * 0.0559+Slope*0.1947+Soil type*0.0551 +Distance from All Weather Roads * 0.1460 + Distance from Dry Weather Roads * 0.1127 + Distance from Foot Paths * 0.0856+ Distance to Towns*0.0854+ Proximity to Rivers* 0.0912 ……………………Equation (2)

Figure 5 clearly gives visual impression and shows the level (Low Moderate High and Extreme) and areas vulnerable to change with the existing factors. Areas surrounding Arjo town, parts of Jamo Giros, Jarso Kamisa Bera, Hara Keku,Wayu Kiltu, Tibe Kusaye, Lalo and north-eastern parts of Hera farm associations were found within extremely to highly vulnerable range for change owing to the extreme probability of the function of the driving factors. The recently settled areas of Bedasa Didessa and Lugema, parts of Hine, the low flat laying Didessa proposed for sugarcane production were identified as highly susceptible for land use/cover transformation. The rest areas of the district fall in the range of moderate to low level of vulnerability to change/transformation.

From the whole area of the district (table 12), 5.84% has low vulnerability to change. This includes steep slopes, inaccessible areas and areas with high probability for flooding such as Didessa river bank.

Much of the area (47.94%) is moderately vulnerable, about 43% is highly vulnerable and about 3% is extremely vulnerable to change.

Although, farmland is not in the extremely vulnerability category, it will be vulnerable to change owing to transformation and loss of or gaining of area/areas from other cover forms. Among the vegetation categories in the area, dense and degraded forest lies within high to extreme vulnerability to change. Wood land is highly vulnerable and grass land is moderately vulnerable to change. A substantial extent of wetlands falls within moderate to high level vulnerability to change.

Table 12: Levels and extent of land use/cover change vulnerability prediction (km^2)

LU/C	Level and Areal Extent of Vulnerability to change				Total Area
	Low	Moderate	High	Extreme	
Farm Land	38.9	266.7	196.9	4.8	507.3696
Dense Forest	0	0.82	4.9	2.7	8.4712
Degraded forest	0	9.3	62.76	15.6	87.7064
Wood land	0.05	22.2	61.3	0.82	84.354
Grass Land	5.8	70.7	7.2	0	83.6712
Wet Land	0.22	0.45	0.15	0	0.818
Bare Land	0.1	0.13	0	0	0.2304
Total	**45.07**	**370.3**	**333.21**	**23.92**	**772.5**
%	**5.84**	**47.94**	**43.12**	**3.1**	**100**

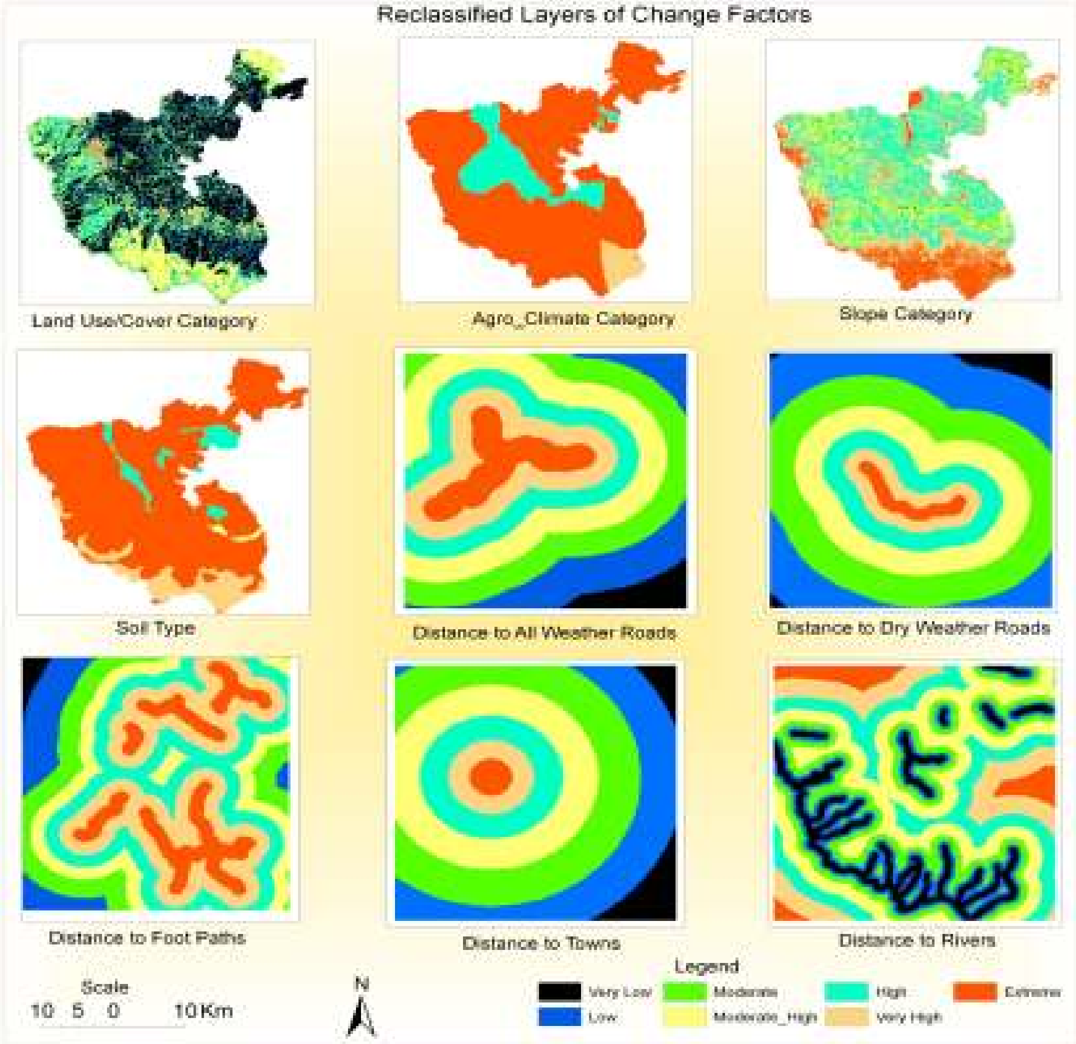


Figure 5: Map of reclassified factor layers of susceptibility to change

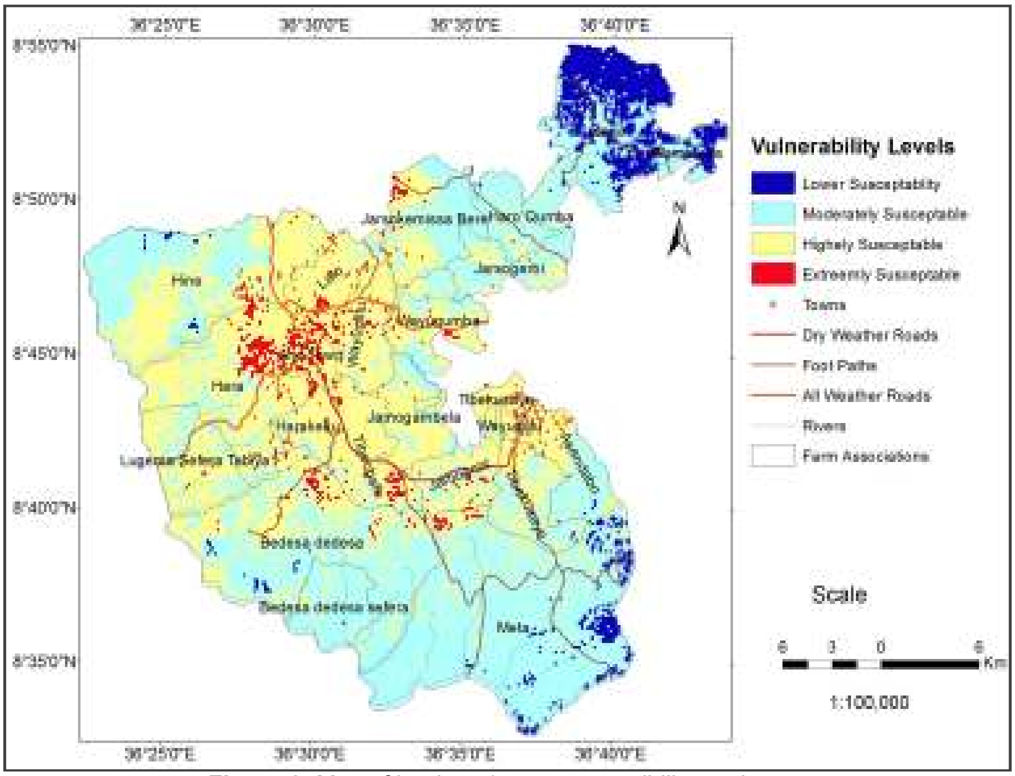


Figure 6: Map of land use/cover susceptibility to change

CONCLUSIONS

The study revealed that a broader change and dynamics of land use/cover has been associated with broader range of impacts on the terrestrial resources of the area during 1973 to 2006. Much of the area has been modified. Strongly steep fragile slopes (>25^0) have been converted to intensively cultivated farmlands. Farmland showed ever expanding, climbing up steep slopes and creating pressure on the remaining vegetation. The biotic diversity and the soils of the area were made susceptible to the impacts and the subsequent degradation. Large patches of the native (natural) vegetations have been converted, modified and some of the rest which are in their natural state were made prone to threats to a degree that surprises. Areas of trees have been most dramatically altered. The original natural dense forest land covering 23.2% of the total area at the initial study period (1973) has dropped down to 1.1% at the final study period owing to conversions to farmland and giving way to derived grass lands, open wood lands and degraded forest vegetations. The degraded forest land has also been converted/modified and left with 11.35%. Wetlands that are supposed to play important roles in maintaining environmental quality, sustaining livelihoods and supporting biodiversity (Turyahabwe Nelson, etal., 2013) were showed reduction in size and left with 0.12% of the original 10.93%.

Recent years signified that the change was more dramatic and rapid. About 46% of the area experienced high to extreme vulnerability to change. Besides farming, the unwise use of forest and natural land resource consumption has to be blamed for the natural land resource degradation over the area.

Conflict of Interest

Conflict of interest none declared.

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