Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 04, pp.14829-14837, April, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

LAND USE/LAND COVER DYNAMICS SINCE THE 1973s IN BISARE WATERSHED, SOUTH RIFT VALLEY OF ETHIOPIA

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ARTICLE INFO

Article History:
Received 14th January, 2015
Received in revised form
22nd February, 2015
Accepted 06th March, 2015
Published online 30th April, 2015

Key words:
Land Use Land Covers (LULC),
GIS,
Bisare watershed,
Rift valley,
Ethiopia.

ABSTRACT

The study was carried in Bisare watershed, south rift valley of Ethiopia. The total area drained by this watershed is around 547 square kilometers. Satellite image and GIS technologies in conjunction with data collected through field surveys, were used to analysis land use/land cover changes that took place in the area between the years 1973 and 2003. In this study, Landsat satellite images MSS (1973), TM (1984) and ETM+ (2003) data were used to identify the land use/land cover status of the area. Based on maximum likelihood classifier, the area was classified into five major land use/land cover classes such as cultivated land, wooded-grass land, shrub and bush land, grass land, and bare land. An increase of 11,596.4 ha (8.3% in the first period (1973-1984) and 12.9% in the second period (1984-2003)) of cultivated land was observed. It was found that much of the current cultivated land is established at the expense of shrub and bush land. A total of 3,993.1ha, 5,360.6 ha, and 5,251.2ha of wooded-grass land, shrub and bush land, and grass land were lost or converted to another land use/land cover type during the study period. More than a four-fold increase of bare land i.e. 3,008.5ha was observed during the study period.

INTRODUCTION

Different factors and mechanisms drive land use/land cover transformation. In many cases, climate, technology, population density, and economics appear to be determinants of land use/land cover change at different spatial and temporal scales (FAO/UNDP, 1986; Muluneh, 2001). Land use/land cover is something which is always in a state of change, involving either conversion from one form of land use/land cover to another or modification of condition within the same land use/land cover category (Muluneh, 2001). Accurate information on land use/land cover changes and the forces and process behind is essential for designing a sound environmental planning and management (Anderson *et al.,* 1976; Ermias, 2007; Grubler, 1994). It provides the baseline data required for proper understanding of how land was used in the past and what types of changes are to be expected in the future (Belay, 2002; Gete, 2000; Olorunfemi, 1983; Pyrovetsi and Michael, 1986). Such analysis is of great use to the resource manager because it provides information that would help in resolving conflicts between human use of natural resources and the function of natural systems (Pyrovetsi and Michael, 1986). So far no studies concerning land use/land cover have been carried out in the whole of the Bisare watershed. Therefore, this study attempts to analyses the extent and pattern of Land use/land cover changes in Bisare watershed. And, it was undertaken with the following specific objectives: (i) to analyze the temporal and spatial dynamics of land use/land cover change and (ii) to highlight the implications of the changes for future watershed management.

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MATERIALS AND METHODS

Site Description

The study was carried out in Bisare watershed (Figure 1), which is found in Southern rift valley of Ethiopia which is a tributary of Bilate river. It is located between 6040′55″ N to 6058′21″ N latitude and 37047′42″ E to 3803′8″ E longitude and contains a very rugged topography with elevations ranges from 1220 to 2270 m.a.s.l. The total area drained by the Bisare watershed is around 547 square kilometers. Lithologically most of the area is covered with Alluvium, Colluviums, and Basalts (Alemayehu *et al.,* 2001). The climate of the Bisare watershed is strongly related to the altitude. It has a sub-humid climate with long-term mean annual rainfall of about 781-1375 mm and precipitation generally concentrated between June and September as shown in the (Figure 2). Temperature varies between 12^0C in rainy season and 28^0C during the dry season. The average temperature is 21 ^{0} C. According to FAO (1998), the six major soils identified in the study area are: - Chromic Vertisols, Chromic Luvisols, Eutric

Leptosols, Eutric Nitosols, Pellic Vertisols, and Vitric Andosols.

BoSP (2004), the total number of population in the study area was estimated to be 150, 273 in 2004.

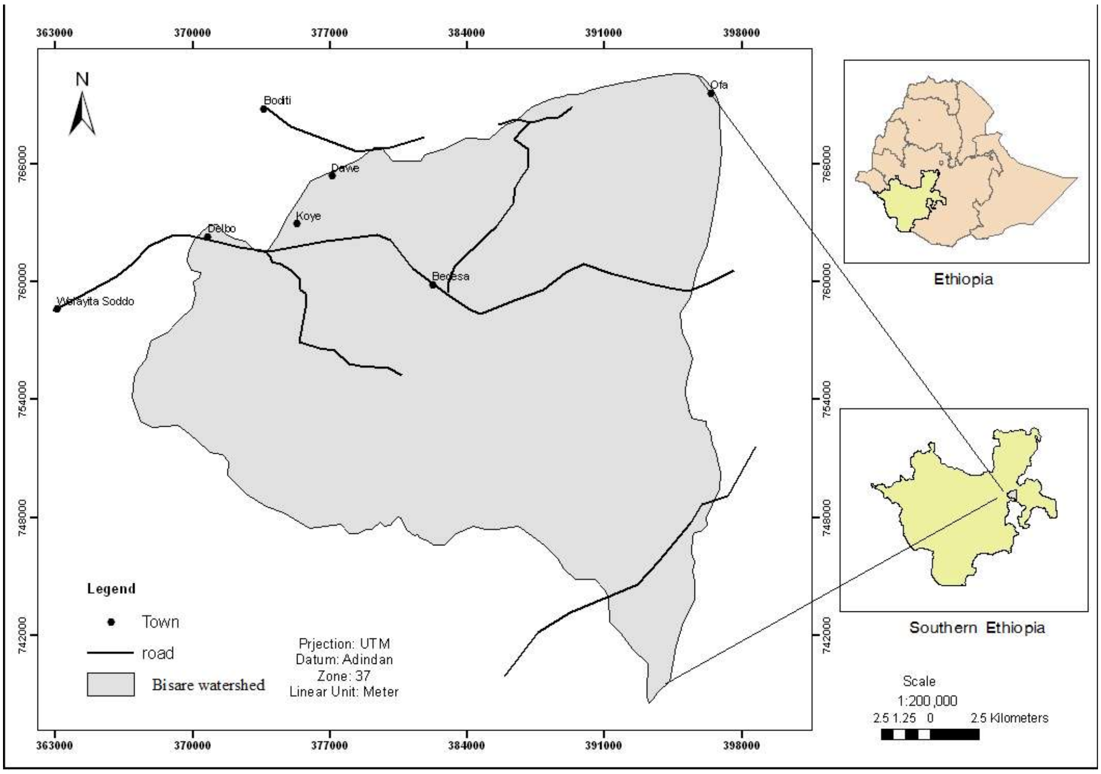


Figure 1. Location map of the study area (Source, ArcGIS result of the study)

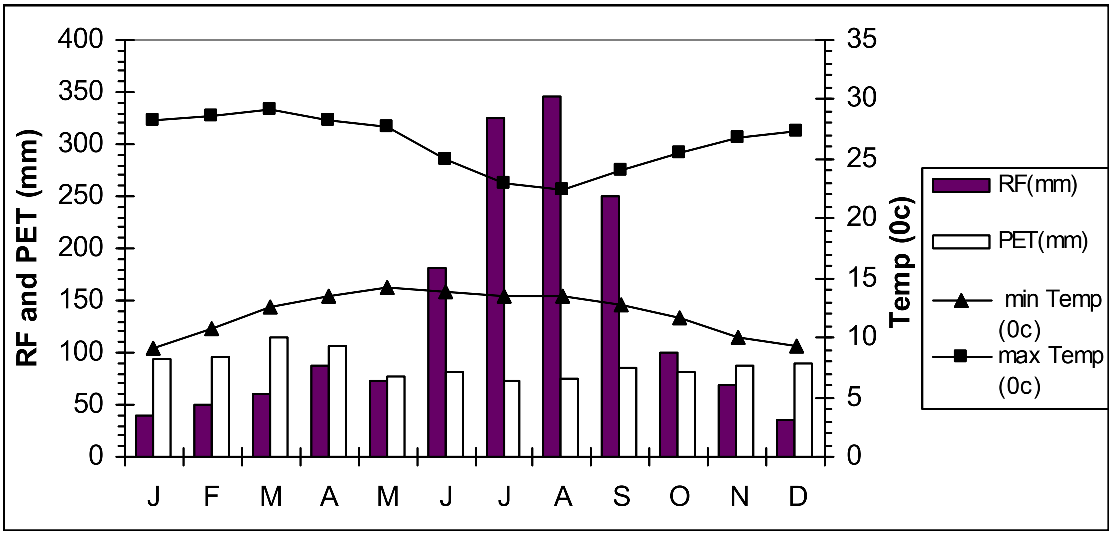


Figure 2. Long-term average monthly rainfall (RF), potential evapotranspiration (PET) and temperature (Temp) in Bisare watershed

Agriculture, in which subsistent rain-fed crop cultivation is practiced, supplemented with some livestock production, constitutes the basis of the economic activity for the majority (87%) of the population living in the area (Alemayehu *et al.,* 2001). Crop cultivation is carried out on land ranging from gentle to very steep slopes. Maize (*Zea mays*), Teff (*Eragrotis teff*), wheat (*Triticum spp*.), and sweet potato (*Ipomoea batatas*), are among major crops and tuber cultivated while a large population of cattle, goat and sheep are reared along the farm mostly in downstream of the watershed. According to

Data Sources

A reconnaissance survey of the area was conducted to collect primary data and to understand the land use-landscape relationship. Toposheets of the area were scanned and geo-referenced using ArcGIS9.1 software. Verification of the boundaries of preliminary land cover map was performed using this information. After setting the boundary, monitoring of land use/land cover changes in the study area was carried out using available digital satellite images data. A combination of information collected from the field, a large-scale topographic map (1:50,000 and 1:250,000) which was developed by Ethiopian Mapping Authority (EMA), and a Landsat Multi Spectral Scanner satellite image (hereafter MSS image) from 1973, a Landsat Thematic Mapper satellite image from 1984 (hereafter TM image) and a Landsat Enhanced Thematic Mapper plus satellite image from 2003 (hereafter ETM+ image). A brief description of the satellite images used is given in Table 1. Identification of some of the land use/land cover classes required a number of field visits and discussions with local community, to have a clear understanding of the main land use/land cover types.

Image Classification

Classification level denotes the level of thematic detail for classification. Since the level of classification is dependent on the image spatial resolution, the level of classification for this study was set taking the image's information capability into account. Landsat satellite image is appropriate for performing a first level classification (Jensen, 1996).

Supervised image classification was conducted; best results were obtained from maximum likelihood classifier. Data collected in the field were superimposed on the images for verification so that the point where the data were collected could be located on the images. Using this classifier, Bisare watershed was classified into five land use/land cover classes namely; cultivated land, wooded-grass land, shrub and bush land, grass land, and bare land (Table 2). An intensive field checking was undertaken in order to collect ground truth information using Global Positioning System (GPS).

Image Analysis

From the digital data, a false color grid composite image was developed (using ERDAS 8.6 virtual GIS analyzer), as it believed to be the best for monitoring and classifying land use/land cover changes (Anderson *et al*., 1976; Sing, 1989). Interpretation of the false color composite image was made based on vegetative biomass cover difference. Using the arithmetic combination of two grids, the slope and the land use/land cover grid, temporal and spatial changes of land use/land cover classes were analyzed.

Subsequently, with the help of grid filtering techniques, major land use/land cover classes were separated and their extent and changes were analyzed for the study period. Quantified values were generated automatically using Spatial Analysis tool in Raster Calculator, ArcGIS 9.1 software. The assessment of classification accuracy is a critical step as it allows a degree of confidence to be attached to the classifications for their effective end use. The ground truth data were utilized in the maximum likelihood report as the independent data set from which the classification accuracy was compared.

An overall accuracy of 86.08% was achieved with a Kappa coefficient of 0.8. According to Anderson *et al.* (1976) the minimum level of accuracy in the classification of land use/land cover from remote sensor data should be at least 85%. The classification accuracy of the study meets this requirement.

Table 1. Satellite images used in land use/land cover classification

Satellite type	Sensor	Number of bands	Pixel spacing (m)	Observation date	RMS error	No. of ground control points
Landsat 4	MSS	4	82 x 82	January 31 1973	0.32	12
Landsat 4	TM	7	30 x 30	22 December 1984	0.30	14
Landsat 7	ETM+	7	30 x 30	2 January 2003	0.28	15

Table 2. Land use/land cover classes considered in image classification and changes detection

Level I category classification	Land use/land cover classes	Brief description
1	Cultivated land	This unit includes areas used for rainfed and irrigated cultivation, including fallow plots and a complex unit, i.e. cultivated land mixed with bushes and trees, and rural homesteads. Include field plots used for production of both annual and perennial crops (Gete, 2000).
2	Wooded-grass land	An open mixture of trees and shrubs standing among a good growth of grass but not forming a canopy over it (Hurni, 1985).
3	Shrub and bush land	Areas with more than 50 per cent shrub and bush canopy (mixed with trees) and less than 50 percent grass cover. The dominant plant forms, i.e., the shrubs, constitute the non-herbaceous plants that branch out at the base of their stem and usually grow only to heights of less than 5 meters (Gete, 2000).
4	Grass land	Areas with less than 20 per cent shrub and tree canopy but more than 80 per cent grass cover. And it is with permanent grass cover, used for grazing; usually communal (Gete, 2000).
5	Bare land	Areas, which have little or no vegetation, cover, mainly with classic gullies and exposed rocks (Belaye, 2002).

Table 3. Comparison of areas under different land uses/land cover change during the three periods

Land use/Land cover class	1973		1984		2003		Percent change in Land use/Land cover		
	Area (ha)	%	Area (ha)	%	Area (ha)	%	1973-1984	1984-2003	1973-2003
Cultivated land	24068	44.04	28608.1	52.35	35664.4	65.27	+8.3	+12.9	+21.2
Bare land	820.5	1.50	3117.9	5.71	3829	7.01	+4.2	+1.3	+5.5
Wooded-grass land	11487	21.02	10502.4	19.22	7493.4	13.71	-1.8	-5.5	-7.3
Shrub and bush land	8970.8	16.42	6399.9	11.71	3610.2	6.61	-4.7	-5.1	-9.8
Grass land	9353.7	17.12	6071.7	11.11	4103	7.51	-6	-3.6	-9.6

RESULTS AND DISCUSSION

Spatio-temporal Land Use/Land Cover Dynamics in Bisare Watershed

Five major land use/land cover classes were identified on the 1973, 1984, and 2003 satellite images. Such as cultivated land, wooded-grass land, shrub and bush land, grass land, and bare land. The land use/land cover data of these years indicated both types of changes: - conversion and modification. In all the periods considered, cultivated land constituted the predominant class of land use/land cover in the Bisare watershed (Table 3). Land use/land cover changes for Bisare watershed were computed from the loss and gain for each level I land use/land cover types between each of the year. A change that is positive indicates that the land cover size increased and a change that is negative indicates that the land cover size decreased. During the years 1973-1984 (1st phase) it was observed that, there is an increase of 4,540.1ha and 2,297.4ha of cultivated land and bare land respectively. At the same period it was also found that, there is a loss of 984.6ha, 2,570.9ha, and 3,282ha of wooded-grass, shrub and bush, and grass land respectively (Table 3).

During the years 1984-2003 (2nd phase) it was observed that, there is an increase of 7,056.3ha and 711.1ha of cultivated land and bare land respectively. At the same period it was also found that, there is a loss of 3,008.5ha, 2,789.7ha, and 1,969.2ha of wooded-grass, shrub and bush, and grass land, respectively (Table 3). It was observed that there is a sharp increase, more than four-fold increase of bare land i.e. about 3,008.5ha, from 820.5ha in 1973 to 3,829ha in 2003. Similarly it was observed that, a total decrease of 3,993.1ha and 5,251.2ha of wooded-grass land and grass land, respectively (Table 3).Generally the progressive increase of cultivated land and bare land was observed in all the years, while there was a noticeable decrease in other land use/land cover type i.e. shrub and bush land, wooded-grass land, and grass land.

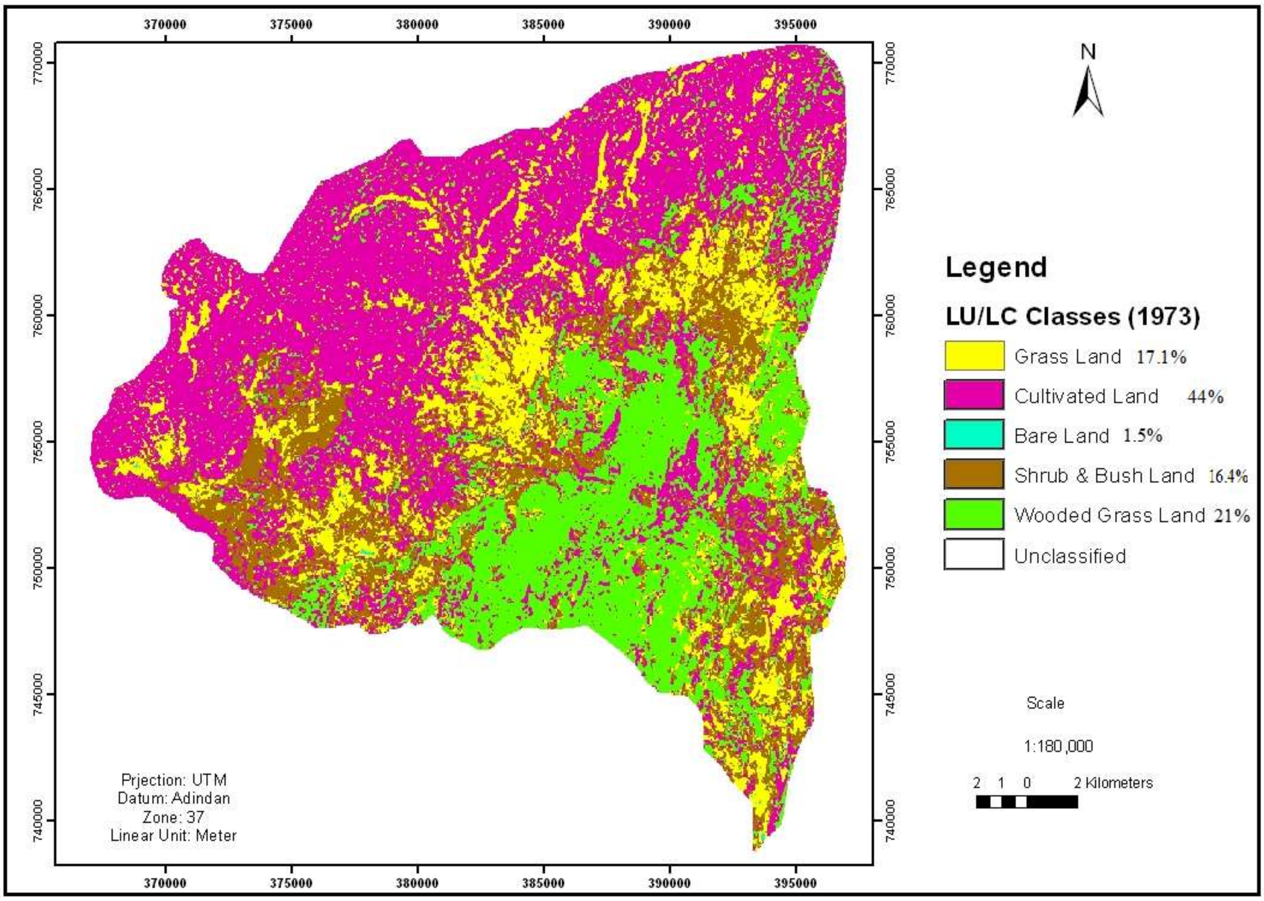
Land use/land cover map of Bisare watershed, 1973 (top), 1984(Middle), and 2003(top)

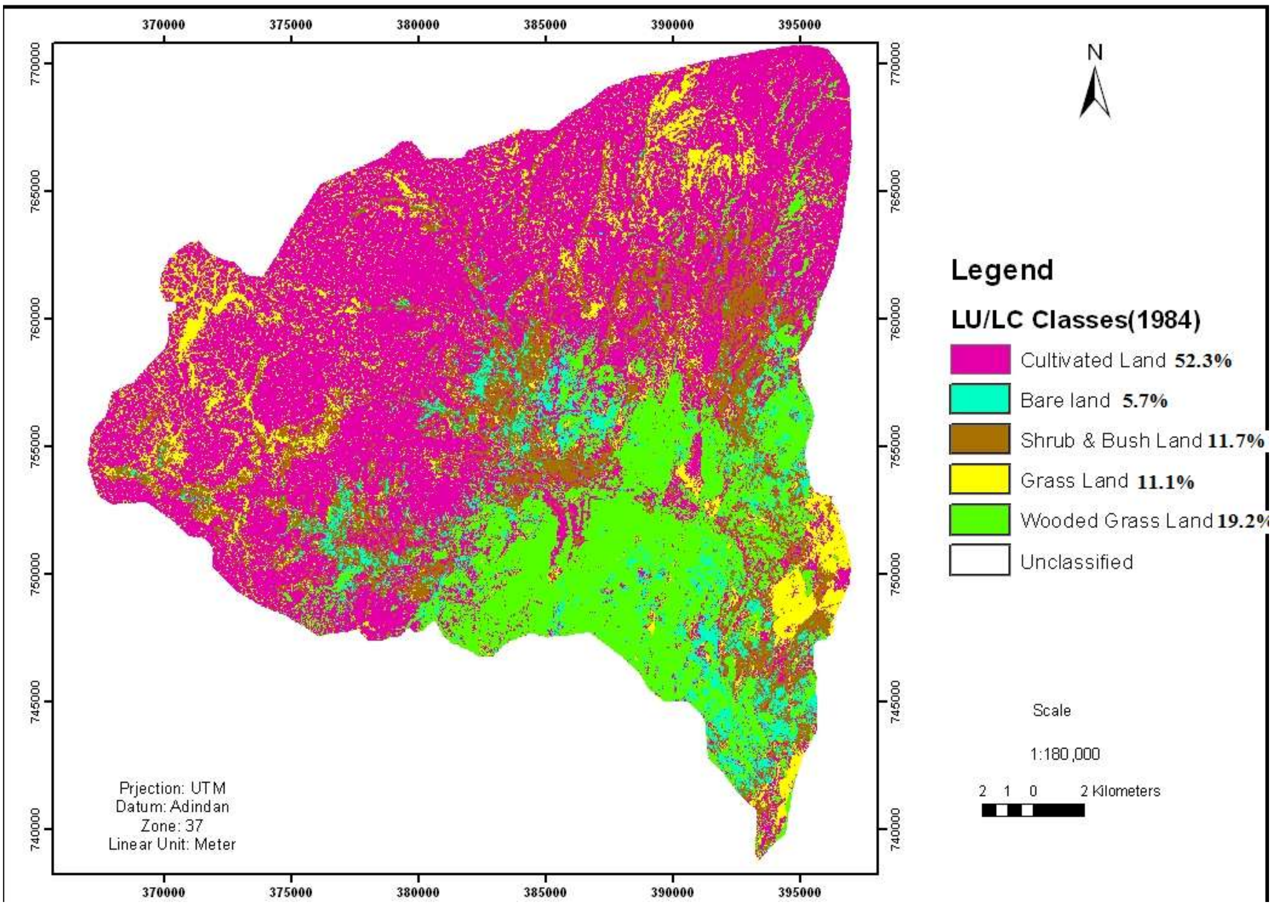
There was an increase of 11,596.4ha of cultivated land during the study period(1973 -2003) and much of this cultivated land is established at the expense of shrub and bush land, 71% of the total gain area i.e. 8,233.4ha. The remaining 3,363.0ha of cultivated land gained from wooded-grass land (35%), grass land (21%), and bare land (5%) (Table 3). Nevertheless, detailed field checking done in 2007/2008 showed that there continues to be a persistent push to cultivate the remaining shrub and bush lands and marginal areas. The table below (Table 4) lists the initial state classes of each land use/land cover type in the columns, the final state classes of each land use/land cover type in the rows and the unchanged areas in the diagonal cells. For each initial state class (i.e., each column), the table indicates how these classes were classified in the final state image. In another words the columns describe at what expense the new land use/land cover classes were established.
The wooded-grass land, which apparently constituted the climax vegetation cover of the region, and accounted for 21.0% of the watershed in 1973, declined to 19.2% in 1984, and further dropped to 13.7% in the year 2003. These figures suggest that wooded-grass land was disappearing at the rate of 0.16% and 0.29% per year between the first and the second period, respectively, which result in clearing of 3,993.1ha of the wooded-grass land; at rate of 133.10ha per year. The cleared areas were converted in to cultivated land (35%), bare land (32%), and grass land (11%) (Table 4). Major deforestation of wooded-grass land was occurred during the second period, which results in clearing of 3,008.5ha of wooded-grass land.

Shrub and bush land was disappearing at the rate of 0.43% and 0.27% per year between the first and the second period, respectively, which result in clearing of 5,360.6ha of the shrub and bush land; at rate of 178.69ha per year during the whole study period. The cleared areas were converted in to cultivated land (71%), bare land (11%), and grass land (8%) (Table4). Similarly, grass land was disappearing at the rate of 0.55% and 0.19% per year between the first and the second period, respectively, which result in clearing of 5,251.2ha of the grass land; at rate of 175.04ha per year. The cleared areas were converted in to cultivated land (21%), bare land (25%), and shrub and bush land (18%) during the whole study period. Cultivated and bare land experienced the lowest conversion in to other land use/land cover types. For instance, during the study period (1973-2003), 72% of the cultivated land continued to be under cultivation while the remaining 8% and 20% converted in to grass land and bare land, respectively. Similarly, 80% of the bare land continued to be under degradation while the remaining 15% and 5% converted in to grass land and cultivated land, respectively. This is due to conservation of bare land in some part of the watershed during the study period.

Land Use/Land Cover Changes on Different Slope Classes

It is important to observe the direction and magnitude of land use/land cover changes that occurred on different slope classes over time (Grubler, 1994). Under normal circumstance, steep lands should be used for perennial crops or kept under forest cover, but should not be used for annual crop cultivation (Hurni, 1996). As it can be seen in Figure 4, in 1973 cultivated land was mainly on gentle slopes (< 20 %). The reverse is true with dramatic increase, in 1984 and 2003, especially on steep slopes, i.e. > 30 %. The overall distribution of shrub and bush land and wooded-grass land on the different slope classes in 1973 was remarkable, with a relatively good percentage on slope >30 %. The later indirectly indicates a stable ecosystem. However, after only 11 years (1973-1984), almost all shrub and bush land and wooded-grass land have been cleared from all slopes, including about 60% of the shrub and bush on steep slopes, and converted to cultivated land (Figure 4). It is also found that cultivated land was the dominate land use/land cover in all slopes in the watershed. Considerable loss of vegetation cover was observed in all the slope classes. One interesting point is that out of the remaining shrub and bush land cover in 2003, about 90% was on very steep slopes and around religious area (churches and mosques) that are not easily accessible in Ethiopia because of cultural taboo.


Legend
LU/LC Classes (1973)
Grass Land 17.1%
Cultivated Land 44%
Bare Land 1.5%
Shrub & Bush Land 16.4%
Wooded Grass Land 21%
Unclassified
Scale
1:180,000
2 1 0 2 Kilometers
Prjection: UTM
Datum: Adindan
Zone: 37
Linear Unit: Meter


Legend
LU/LC Classes(1984)
Cultivated Land 52.3%
Bare land 5.7%
Shrub & Bush Land 11.7%
Grass Land 11.1%
Wooded Grass Land 19.2%
Unclassified
Scale
1:180,000
2 1 0 2 Kilometers
Prjection: UTM
Datum: Adindan
Zone: 37
Linear Unit: Meter

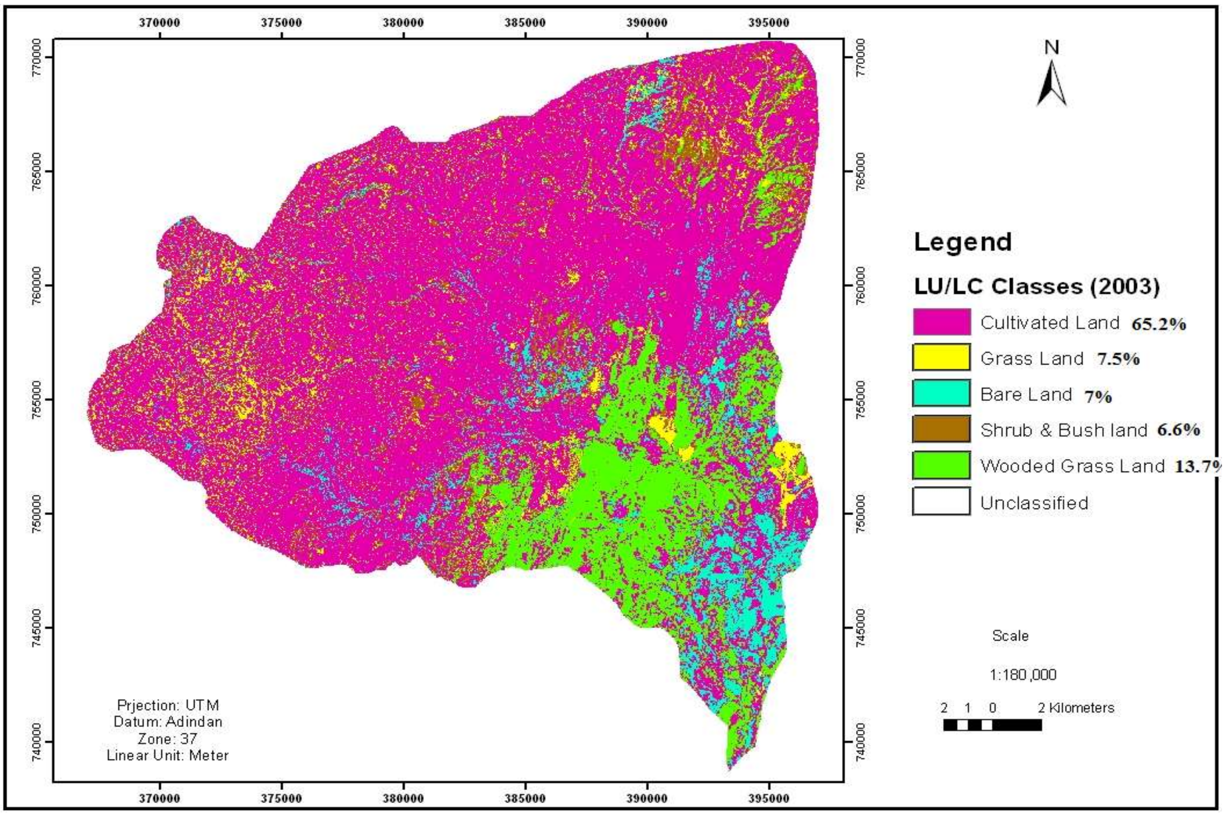


Figure 3. Land use/land cover map of Bisare watershed, 1973 (top), 1984(Middle), and 2003 (top)

Table 4. Transition between the major land use/land cover classes (area in %) in Bisare watershed

LU/LC Types	W-G L	S and B L	CL	GL	BL
1973-1984 (1st period)					
W-G L	**40**	3	25	12	20
S and B L	0	**44**	30	11	15
CL	0	0	**75**	10	15
GL	5	5	25	**55**	10
BL	0	2	10	16	**72**
1984-2003 (2nd period)					
W-G L	**31**	1	32	15	21
S and B L	0	**32**	40	10	18
CL	0	0	**78**	12	10
GL	2	9	38	**41**	10
BL	0	0	10	20	**70**
1973-2003 (total study period)					
W-G L	**22**	0	35	11	32
S and B L	0	**10**	71	8	11
CL	0	0	**72**	8	20
GL	0	18	21	**36**	25
BL	0	0	5	15	**80**

W-G L: - Wooded-Grass Land
S and B L: - Shrub and Bush Land
CL: - Cultivated Land
GL: - Grass Land
BL: - Bare Land
LU/LC: - Land Use/Land Cover

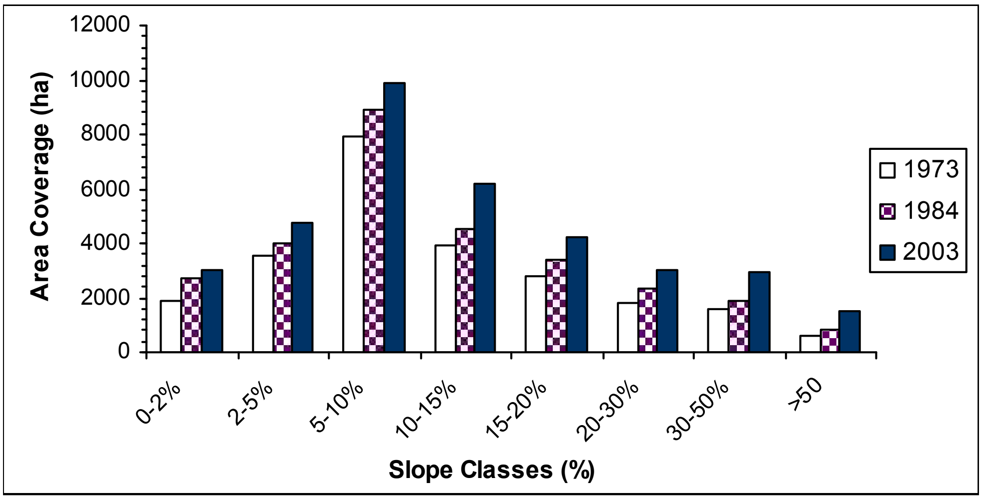


Figure 4. The magnitude and distribution of cultivated land on slope classes

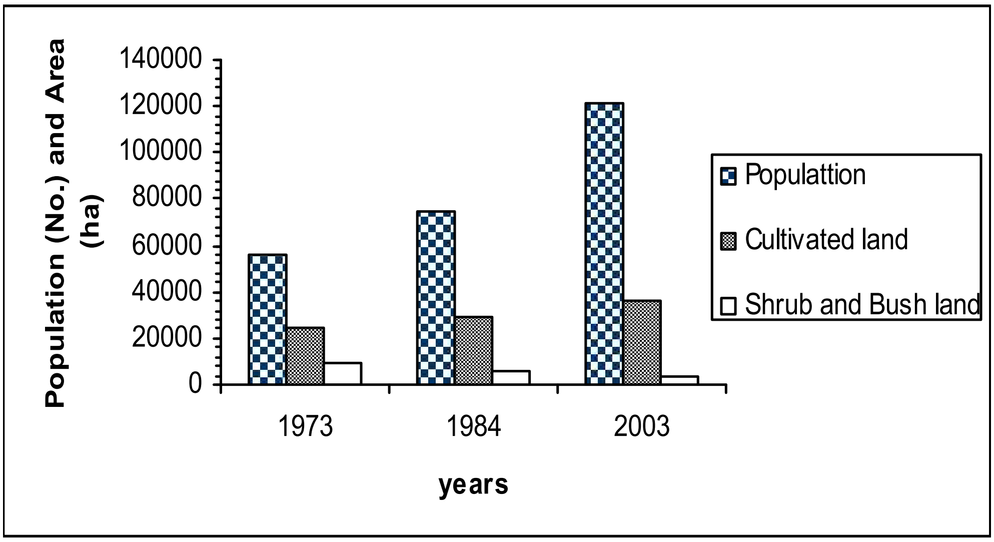


Figure 5. Population and major land use/land cover changes in the study period

Implications of the observed land use/land cover changes

If land use/land cover changes are not carried out systematically, the negative impacts on both the environment and the socio-economic settings are not easily measurable (Aklilu, 2006; Lambin, 2003). The changes may be multi- or unidirectional (Gete, 2000; Pyrovetsi and Michael, 1986). But in this study it is investigated that the land use/land cover changes were dominated by unidirectional changes; wooded-grass land and shrub and bush land were consistently converted to open areas, cultivated land, and bare land, etc. and not vice versa. The observed land use/land cover changes in the area seem to be unanticipated under very traditional farming system. Observation in the watershed show that clearing of wooded-grass land, shrub and bush lands especially on steep slopes and pushing grass lands to marginal areas are considered as main causes for the hasty land use/land cover changes. Densely populated society together with a continuous redistribution of land in the country since 1975 caused many farmers to feel insecure (Alemayehu *et al.,* 2001; Gete, 2000; Hurni, 1986).

In Ethiopia, the redistribution of land without due consideration to the environment was the major activities which contributed to the devastating clearance and conversion of vegetation covers in to cultivated lands (Azene, 2001; Hurni, 1993), this is also very true in the study area. Its manifestations are detected by high sharp decline of vegetation cover and gully formation across the grazing and ploughing fields. The change did not happen without adverse results. For instance, as cultivated land was expanded at the expense of all land use/land cover units, especially shrub and bush land; grass land was pushed to marginal areas resulting in less available feed and thereby in a reduction in livestock number and quality.

Comparisons done between major land use/land cover changes and population dynamics showed that with population increase, there is an increase in cultivated land in greater proportion, while shrub and bush land declined drastically (Figure 5). The total population of Bisare watershed in 2003 was 121,464. The projected value, with a 2.7% per year (BoSP, 2004), average growth rate of 1984 was 74,617.

Assuming that the average rate of population increase in the whole watershed remained constant, the population of the studied area would have been around half of its current size about 30 years ago i.e. 1973. At this point it might be worthwhile to mention the controversial issues related to the impact of population growth on resource degradation as stated by Hurni (1996). “In the absence of sound implementation of environmental policy, unchecked population growth is usually considered the primary culprit in resource degradation”. However, others (Tiffen *et al*., 1994, quoted in Hurni, 1996) argue that the reverse is true, i.e. more people, less degradation. Because of the reasons mentioned above and others, population in one way or another has been contributing to the dramatic land use/land cover changes seen in the area. Beyond the reduced possibility for cultivated land-expansion and severe shortage of land, one of the immediate impacts of the thinning and destruction of the shrub and bush land is shortage of fuel wood and construction materials for the local community. This condition forces farmers not only to travel very long distances to collect wood, but also to increasingly burn crop residues and organic manure for cooking and heating.

Conclusion

The land use/land cover changes analysis (in time and space scale) done in this study, shows that land use/land cover changes in the area were very drastic and unmethodical. It was found that during the study period (1973-2003), there is sharp increase in cultivated land and bare land, which results in increase of 11,596.4ha and 3,008.5ha, respectively; while there is a sharp decrease in grass land, shrub and bush land, and wooded-grass land, which result in clearing of 5,251.2ha, 5,360.6ha, and 3,993.1ha, respectively. It was observed that, irrespective of slope steepness, almost every land unit has been converted to cultivated land. Cultivation pushed onto marginal lands and land management has greatly deteriorated. Its manifestations are detected by high sharp decline of vegetation cover and gully formation across the grazing and ploughing fields.

The striking land use/land cover changes observed have been caused by a combination of many factors. Such as the intensification, lack of vegetation cover, the steep slope gradient and the long slope length coupled with high erosive rain, and high population density have been found to be the root causes of such harsh land use/land cover dynamics and the problem associated with it. This study has provided important insights into the dynamics that occurred in the study watershed in between 1973 and 2003. Building upon this, careful investigations of the existing biophysical, socio-economic, and institutional conditions seem appropriate. Accordingly, an introduction of proper land management, population growth control mechanisms, stable institutional set-ups (that have an environmental protection mandate), and integrated environmental rehabilitation are some of the issue that need be given high priority.

Acknowledgement

Financial support for this research was provided by Canadian International Development Agency (CIDA) through UPDU Ethiopian project under capacity building for post-graduate students. We are so grateful of the project for funded this research works.

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APPENDICES

Appendix 1. poor resource management in Bisare watershed near Bedesa River

Figure 1. Result of poor resource management in Bisare watershed near Bedesa River (Photo by the author)

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