International Journal of Ecology and Environmental Sciences 40 (4): 225-231, 2014
ISSN: 0377-015X (Print); 2320-5199 (Online)

GIS- based Land-Cover Change Detection in the Habitats of the Gelada Population in Guassa Community Protected Area, Ethiopia

ESHETU MOGES AND M. BALAKRISHNAN*

Department of Zoological Sciences, Addis Ababa University, PO Box 1176, Addis Ababa, Ethiopia

Author for correspondence: E-mail: balak212@yahoo.com

ABSTRACT

Information on land-use/land-cover changes in protected areas is essential for a wide range of applications, especially to analyze land degradation, runoff, changing patterns of natural resources and to resolve wildlife management related issues. Understanding the effects of the changes on biodiversity is important to reduce loss of biodiv–ersity, and to insure long-term persistence of natural resources and wildlife. In the present study, satellite imageries LANDSAT TM and LANDSAT ETM+ (1986, 2000, and 2013) were used to assess spatio-temporal land-use/land-cover changes in Guassa Community Protected Area for a period of 27 years (1986 – 2013) to identify major changes in vegetation patterns and to discuss the implications of changes in the extent of grasslands on the geladas in the area. In the study area, the extents of forest and *Erica* have increased, while the extents of grassland, *Hilichrysum* and shrubland have decreased during 1986 – 2013. Due to the effects of anthropogenic and climatic factors, the extent of grassland available in1986 had decreased to 0.74 km^2 in 2013. As geladas are known mainly to depend up on grasses for food, the land-cover changes detected in the study area would lead to increased dependency on grasses interspersed in other land-cover types such as *Hilichrysum* and *Erica* habitats.

Key Words: Accuracy Assessment, Habitat Change Detection, Land-use Changes, Remote Sensing.

INTRODUCTION

Changes in land-use land-cover can be detected on temporal and spatial scales using modern tools such as remote sensing (Wickham et al. 1999, Lung and Schaab 2009). The increase in human population and related activities demand the limited land and soil resources for agriculture and pasture land-uses, which act as driving forces for habitat alteration (Ayhan et al. 2004, Prakasam 2010). Degradation of habitat connectivity in between landscapes occurs due to fragmentation and anthropogenic activities, which also cause depletion of biodiversity. Information on the rate and kind of changes in the use of land resources is essential for proper planning and management of natural resources (Bradley and Smith 2004).

Ethiopia is one of the most populous countries in Africa, and is experiencing major changes in the land-use/land-cover patterns from natural vegetation to farming practices and human settlements (Hurni et al. 2005, Mengistie et al. 2013). Land-cover dynamics is more severe in the Ethiopian highlands, which accounts for nearly 44% of the country's landmass, and have been in farming practice for millennia (CSA 2007). Ethiopia is currently facing serious problems to manage and conserve natural resources, especially in the protected areas in view of human and livestock population growth (Amsalu and Graaff 2006, Diress et al. 2010).

Sustainable use of natural resources, and retaining vast natural landscapes under protective coverage are essential to attain the goal of conservation and sustainable natural resource management (Eshetu and Högberg 2000, Mengistie et al. 2013). In this regard, spatial data monitoring and evaluation of the status of natural habitats of endemic wildlife are critical. Land-use/land-cover analysis using remote sensing is considered as a valuable tool to study wildlife habitats and to formulate effective management strategies (Campbell 1991, Reddy et al. 2011, Yadav et al. 2013). Social and economic forces ranging from local to regional, may drive land-use decisions that influence the spatial pattern and rate of changes of ecosystems (Norman et al. 2012). Assessing the vulnerability of human and biological communities to changing ecosystem services is possible using GIS-based multi-criteria decision support tools (Alcorn 1994, Campbell 1991).

Changes in land-use patterns have tremendous influence on grassland habitat, which is the main source of food of gelada populations. Pressures on grassland or tussock grass in the study area were due to human dependence for settlements and utilization of grasses for livestock and for thatching houses. Grassland degradation can thus occur through both functional and structural changes. In the recent past, it has been changed dominantly into shrubs and *Hillchrysum* habitat types, which are not serving as food sources of geladas. Hence, the present study is aimed to analyse land-cover changes in the study area for the past 27 years (1986 – 2013) in connection with the endemic gelada population in the area.

THE STUDY AREA

The Guassa Community Protected Area (GCPA) is one of the high altitude ranges in the central highlands of Ethiopia located at a distance of 265 km northeast of Addis Ababa, and 135 km north from the Zonal capital (Debre Birhan). This area lies between 10° 15’ – 10° 27’ N latitude and 39° 45’ – 39° 49’ E longitude (Figure 1). The GCPA with a total area of 111 km^2 (including settlements), forms part of the western edge of the Great Rift Valley, at an altitude range of 3,200 – 3,700 m asl. Rainfall of the area is characterized by a bimodal pattern. The major wet season occurs during June – September and a short rainy season during February – April. The annual rainfall ranges from 1,200 to 1,600 mm. Temperatures of the area is characterised by mild days and cold nights. In the driest months (December – February), day time temperature rises up to 25°C, while night time temperature falls up to -7°C (a diurnal fluctuation of 32°C). The area is characterized by high altitude vegetation types. Traditional indigenous management of natural resources in the area has helped the survival of various species of endemic fauna and flora that are locally extinct in other similar parts of the country (Zelealem and Leader-Williams 2005, Zelealem et al. 2012).

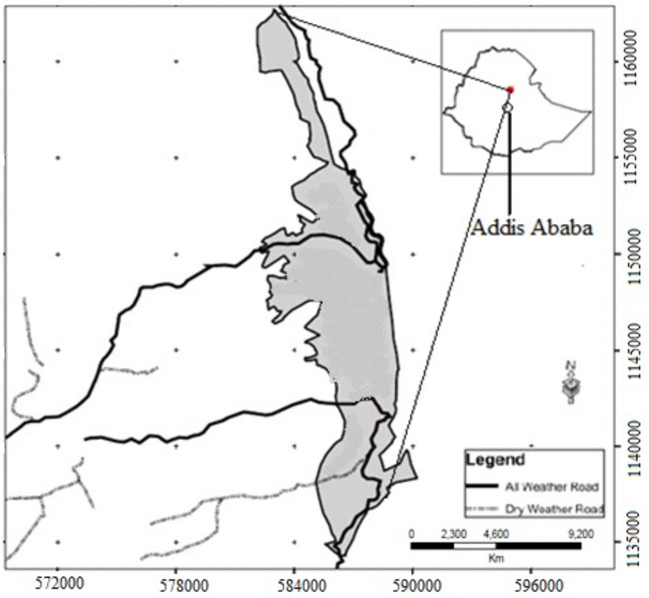

Figure 1. Map of the study area

METHODS

Changes in the vegetation patterns were detected using LANDSAT TM and ETM+ imageries of years 1986, 2002 and 2013, owing to their good spectral and temporal resolution and moderate spatial resolution (acquired from the Global Land Cover Facility - GLCF; www.glcf.org) through the Earth Science Data Interface (ESDI). To make the images of the three years compatible, all the LANDSAT TM (58 m), ETM+ (30), and ETM+ (60 m) images were re-sampled to a 60×60 m^2 pixel using the nearest neighbor re-sampling technique (Ediriwickrema and Khorram 1997). Six land-use/land-cover classes were identified for image classification based on the classification criteria of Allen (1992) and Alvo and Ponomarenko (2003). A list of land-cover categories in the area is given in Table 1.

A pixel-based supervised image classification with maximum likelihood classification algorithm was used to map the land-use/land-cover classes. A total of 200 random points distributed evenly across the study area were generated and these locations were sub-sampled based on accessibility, locality and logistical feasibility. A total of 80 ground truth observation points were used for the Maximum Likelihood Classifier Technique.

Table 1. Description of land-cover categories in the study area*

Land- use /land-cover type	Description of the habitat type
Forest including *Cupressus lusitanica* habitat	Areas covered with trees that have open, or closed canopy cover
Grassland	Grass and herb cover with scattered trees and shrubs
Hilichrysum	A mixture of *Helichrysum* species with afro-alpine vegetation and tussock grass
Farmland	Crop field and pasture land
Shrubland	Areas covered with shrubs and other small sized plant species
Erica moorland	Vegetation typically dominated by mixture of cross-leaved heath plants, usually low-growing shrubs or trees dominated by *Erica*

*Settlement land-cover is not included

Change Detection

Following the classification of imageries, a multi-date post-classification comparison change detection algorithm was used to determine changes in land-covers during the study periods. Classification with high accuracy is a prerequisite for effective change detection using post-classification technique (Mengistie et al. 2013). Images of different reference years were first independently classified using ERDAS Imagine 10. Classified images with highest accuracy were used in the change detection process.

Accuracy Assessment

Accuracy assessments were performed for classified images of 1986, 2002, and 2013. A minimum of 33 random points were generated per class using stratified random sampling approach for efficient accuracy assessment. The corresponding reference classes for each land-use/land-cover types were collected from different data sources, including field visits, aerial photos, topographic maps and raw images. As error matrix-based accuracy assessment is the most common and valuable method for the evaluation of change detection, an error matrix and a Kappa analysis were used to assess the accuracy of changes (Singh 1989, Yuan et al. 2005).

Gelada Home Range

Home range data were gathered following three units, the smallest social system of geladas (Dunbar 1986). They were followed from morning (07.00h) till evening (18.00h) during 2012 – 2014, on an average of 15 days per month. For each day of observation, the area traversed by the gelada unit under observation was recorded using GPS points, and the average range coverage was calculated separately for wet and dry seasons.

RESULTS

Land-use/land-cover Change Detection

The land-cover maps of the year 1986, 2000 and 2013 are presented in Figure 2 a, b and c. These figures provide information on major land-use/land-cover changes in Guassa Community Protected Area during the period under investigation. The extent of land-cover changes per class is presented in Tables 2 and 3.

As indicated in Table 2, forest class change with the respective classes accounted for 0.56 km^2. The highest transition was 4.05 km^2 to shrubland. Class change of grassland with the respective classes was 6.62 km^2 and the highest transition was 3.75 km^2 to *Hilichrysum*. *Hilichrysum* land-use change was 15.24 km^2 with the highest transition of 10.26 km^2 to shrubland. Farmland land-use change was only 0.01 km^2, shrubland 4.05 km^2 and *Erica* 18.29 km^2. The highest transitions for the corresponding classes were 0.01, 1.56 and 8.08 km^2 into shrubland and *Erica*. Land-use/land-cover categories, which showed increase in extent are open forest, farmland and shrubland, accounting for 0.86 km^2, 0.11 km^2 and 16.55 km^2, respectively. The average rate of change of forest into corresponding classes was 0.04 km^2/year and the average annual rate of change of shrubland into corresponding classes was 0.34 km^2/year. There was no transition of farmland in to any other category during this period. On the other hand, the land-use/land-cover categories like grassland, *Hilichrysum* and *Erica* vegetation showed decreasing patterns amounted to -0.27 km^2, -3.27 km^2 and -14 km^2, respectively. The average rates of change for these LU/LC classes were 0.47 km^2/year, 1.095 km^2/year and 1.31 km^2/year, respectively. Among the natural vegetation cover types, *Erica* and *Hilichrysum* experienced the lowest persistence, whereas shrubland and forest were the most persistent cover types during the study period.

As indicated in Table 3, when the 2000 LU/LC classification was compared with that of 2013, grassland class change with the corresponding classes accounted for 11.43 km^2, with the highest transition of 5.04 km^2 to shrubland. The forest class change into the corresponding classes was 1.30 km^2 with the highest transition to shrubland. *Hilichrysum* class change with the corresponding classes accounted for 23.91 km^2 with the highest transition of 16.45 km^2 in to *Erica*. The highest transition of farmland, shrubland and *Erica* were 0.08 km^2, 13.2 km^2 and 2.14 km^2 into *Erica* (both farmland/ shrubland) and *Hilichrysu*m, respectively. The *Erica* land-cover type showed increasing pattern, which accounted for 30.15 km^2. The average rates of change of forest and *Erica* into corresponding classes were 0.1 km^2/year and 0.32 km^2/year, respectively. In contrary, the land-use/ land-cover categories like grassland, *Hilichrysum*, farmland and shrubland showed decreasing patterns, which accounted for -8.33 km^2, -12.22 km^2, –0.08 km^2 and -10.73 km^2, respectively. The average rates of change for these LU/LC classes were 0.87 km^2/year, 1.84 km^2/year, 0.01 km^2/year and 1.73 km^2/year, respectively.

Table. 2. Land-use/land-cover changes in the study area during 1986-2000

Land-use/land-cover type		1986 (km^2)						
		Forest	Grassland	*Hilichrysum*	Farm land	Shrub land	*Erica*	Total
2000 (km^2)	Forest	**2.42**	0.22	0.19	0	0.83	0.19	3.85
	Grassland	0.03	**6.39**	2.91	0	0.55	2.9	12.78
	Hilichrysum	0.05	3.75	**14.83**	0	1.10	7.11	26.84
	Farm land	0	0.03	0.06	**0.01**	0.01	0.01	0.12
	Shrub land	0.45	1.73	10.26	0.01	**11.21**	8.08	31.74
	Erica	0.03	0.89	1.82	0	1.56	**2.43**	6.73
	Class Total	2.98	13.01	30.07	0.02	15.26	20.72	82.06
	Class change	0.56	6.62	15.24	0.01	4.05	18.29	
	Image difference	0.86	-0.27	-3.27	0.11	16.55	-14.04	

Table. 3. Land-use/land-cover changes in the study area during 2000-2013.

Land-use/land-cover type		2000 (km^2)						
		Forest	Grassland	*Hilichrysum*	Farm land	Shrub land	*Erica*	Total
2013 (km^2)	Forest	**2.54**	0.53	0.18	0	1.4	0.13	4.78
	Grassland	0	**1.36**	2.76	0	0.41	0.1	4.63
	Hilichrysum	0.32	1.94	**2.90**	0.01	7.44	2.14	14.75
	Farm land	0	0.01	0.02	**0.03**	0	0.01	0.07
	Shrub land	0.76	5.04	4.50	0.01	**8.98**	1.74	21.03
	Erica	0.22	3.91	16.45	0.08	13.20	**2.94**	36.80
	Class Total	3.84	12.79	26.81	0.13	31.43	7.06	82.06
	Class change	1.30	11.43	23.91	0.10	22.45	4.12	
	Image difference	0.95	-8.33	-12.22	-0.08	-10.73	30.15	

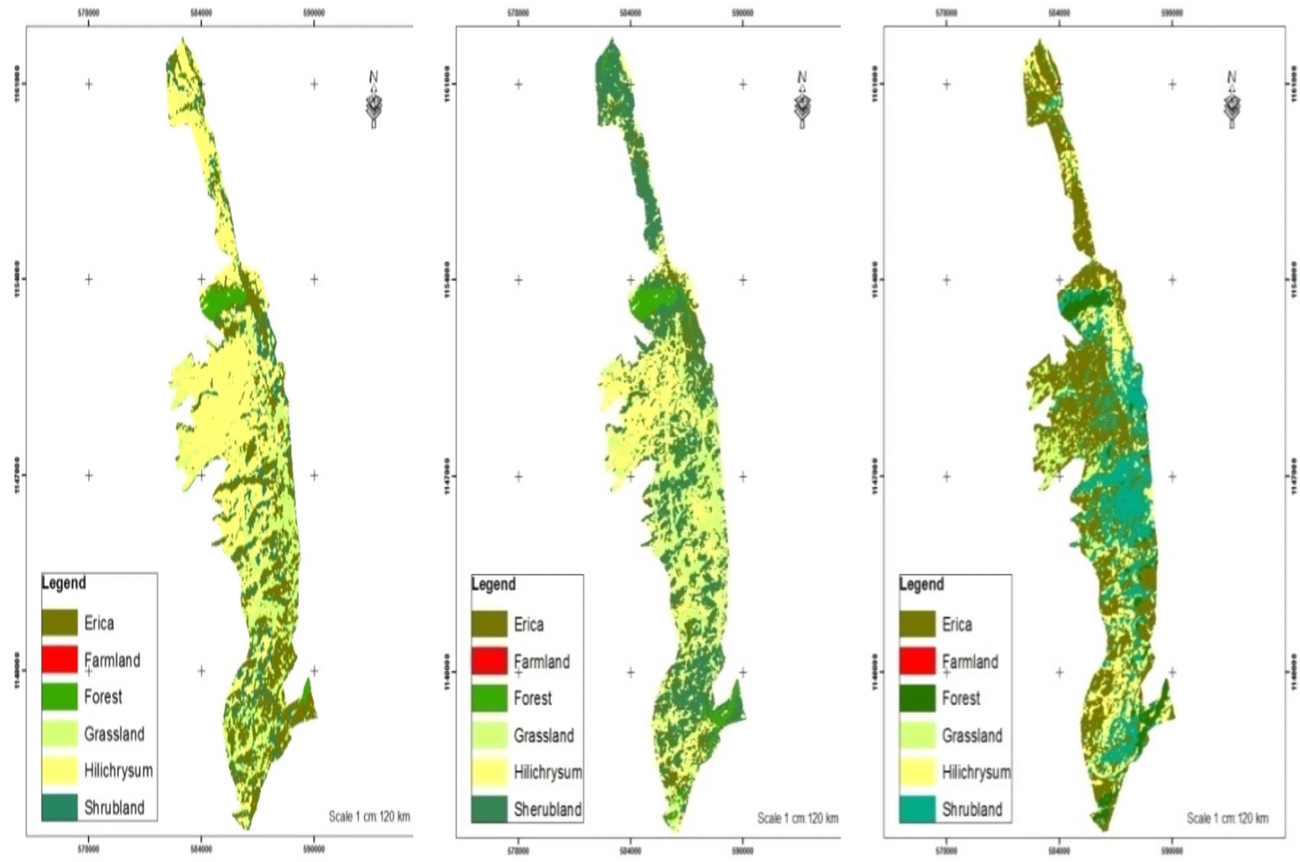

Figure 2a, 2b & 2c.Land-use patterns of the study area for the years 1986, 2000 and 2013.

Table 4. Grassland habitat changes during 1986 -2003 in the study area.

Habitat	Area changed, km^2 Succession type	1986-2000	2000-2013
Grassland	Forest	0.22	0.53
	Hilichrysum	3.75	1.94
	Farmland	0.03	0.01
	Shrubland	1.73	5.04
	Erica	0.83	3.91
Total change	6.56	11.43	

Table 4 gives data on the changes occurred in the extent of grassland habitat during 1986–2013, the habitat of geladas in the study area. A total area of 6.56 km^2 grassland habitat has changed into different land-use types during 1986–2000. Transition of grassland continued further, and 11.43 km^2 was changed during the period 2000 – 2013. On the other hand, change of grassland into different land-use types had increased from 6.56 km^2 to 11.43 km^2, between 1986 and 2013. As compared to the unchanged grassland in the two phases of analysis, the grassland habitat was in a better status during 1986 – 2000, with an extent of 6.56 km^2. The gelada home-range size was 0.72 and 2.4 km^2 in wet and dry seasons, respectively.

DISCUSSION

The land-use/land-cover categories in the study area showed changes during the period of analysis, revealing decrease in the extent of natural habitats in correspondence with the increase in human modified areas. The extent of grassland has been constantly decreasing during the period from 1986 to 2013. This might be due to human induced and related ecological processes. Further, the grassland habitat has a tendency of succession due to direct and indirect impacts of drought and related physical factors. Diress et al. (2010) have shown direct and indirect impacts of drought on LU/LC dynamics in Northern Afar rangelands of Ethiopia. The depletion of the extent of grassland by anthropogenic factors and natural processes might lead to serious impacts on foraging ecology of geladas as they exclusively depend up on grasses.

The *Hilichrysum* habitat also showed decreasing pattern of changes during the period 1986 – 2013. This might be due to the low persistency of this habitat type in the context of increasing human population pressure and related factors such as cattle grazing in the area. Mengistie *et al*. (2013) have noted that the extent of cropland/farmland in Munessa-Shashemene highland, Ethiopia showed increasing patterns in the past couple of decades in response to the demand for more food for the increasing human population around. In contrast to this general trend, in GCPA, transition of other land-use types to farmland was minimal in the recent past. During the initial stage of comparison, shrubland habitat showed changes into other land-use types to an extent of 4.07 km^2. There was higher levels of transition of 22.84 km^2 during the second phase of comparison (2000 – 2013). This major transition could be due to the key driving forces such as severe drought and collection of firewood by the local community. Meze-Hausken (2004) has reported severe droughts as a cause for transition, or a rapid loss of a specific land-cover type in the northern Ethiopia. The shrubland habitat decreased in its extent during 1986 – 2013, probably be due to intensive firewood collection by local people. On the other hand, the *Erica* moorland habitat has increased in the second phase of the present study, which might be as a consequence of better conservation measures undertaken in the area under the Guassa Community-based Conservation Programme (Zelealem and Leader-Williams 2005).

In general, in the landscape in GCPA, major LU/LC changes have occurred in the last 27 years. In the context of conservation of geladas in the study area, the grassland habitat where they mainly forage has decreased in extent, while forest with *Cupressus lusitanica* habitat has increased during the last three decades. About 80% of the *Cupressus* plantation forest was established at the expense of conversion of natural habitat types. The decrease in the extent of grassland in the study area would negatively affect gelada populations. They have to forage in limited extents of grasslands and the available grasses interspersed in other habitat types such as *Hilichrysum* and *Erica* moorland.

The present datasets will form inputs for spatial database that can be used as a model for monitoring future changes to help in decision-making during policy formulation, land-use planning processes and other similar studies in protected areas in Ethiopia and elsewhere in the tropics where similar human socio-economic conditions and attitudes prevail. The present study also supports recent findings on the use of remote sensing-based analysis to be a vital tool for continuous monitoring of LU/LC changes in wildlife habitats and conservation areas at varied spatial and temporal scales.

ACKNOWLEDGEMENTS

We are grateful to the Department of Zoological Sciences, Addis Ababa University for providing financial assistance during this study. Officials of the International Livestock Research Institute (ILRI) and Ethiopian Mapping Authority are thanked for providing imageries of the study area. The Ethiopian Wildlife Authority is thanked for permission for this study in GCPA.

REFERENCES

Alcorn, J. B. 1994. Indigenous peoples and conservation. Conservation Biology **7**: 424-426.

Allen, R. B. (1992). Recce: An Inventory Method for Describing New Zealand's Vegetation: A Field Manual. Ministry of Forestry, Christchurch, New Zealand. 21 pages.

Alvo, R. and Ponomarenko, S. (2003). Vegetation classification standard for Canada workshop. Canadian Field-Naturalist 117: 125-139.

Amsalu, A. and Graaff, J. D. 2006. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. Journal of Environmental Management 83: 448-459.

Ayhan, A.; Ametin, T. and Bgurcan, B. 2004. Spatial and temporal analyses of forest cover change: human impacts and natural disturbances in Bartin forests. Landscape Ecology 19: 631-646.

Bradley, M. P. and Smith, E. R. 2004. Using science to assess environmental vulnerability. Environmental Monitoring and Assessment 94: 1-7.

Campbell, J. 1991. Land or peasants? the dilemma confronting Ethiopian resource conservation. African Affairs 90: 5-21.

CSA 2007. Summary and Statistical Report of the 2007 Population and Housing Census. Central Statistical Authority: Addis Ababa, Ethiopia. 39 pages.

Diress, T.; Moe, S. R.; Vedeld, P. and Ermias, A. 2010. Land-use/cover dynamics in Northern Afar rangelands, Ethiopia. Agriculture, Ecosystems & Environment 139: 174–180.

Dunbar, R.I.M. 1986. The social ecology of gelada baboons. Pages 332-351, In: Rubenstein, D.I. and Wrangham, R.W. (Editors) Ecological Aspects of Social Evolution: Birds and Mammals. Primceton (NJ), Princeton.

Ediriwickrema, J. and Khorram, S. 1997. Hierarchical maximum-likelihood classification for improved accuracies. Geoscience and Remote Sensing 35: 810- 816.

Eshetu, Z. and Högberg, P. 2000. Reconstruction of forest site history in Ethiopian highlands based on C13 natural abundance of soils. Ambio 29: 83– 89.

Hurni, H.; Tato, K. and Zeleke, G. 2005. The implications of changes in population, land use, and land management for surface runoff in the Upper Nile Basin Area of Ethiopia. Mountain Research and Development 25: 147–154.

Lung, T. and Schaab, G.2009. A comparative assessment of land cover dynamics of three protected forest areas in tropical eastern Africa. Environmental Monitoring and Assessment 161: 531-548.

Mengistie, K.; Schneider, T.; Teketay, D. and Knoke, T. 2013. Land-use land-cover change analysis using object-based classification approach in Munessa Shashemene landscape of the Ethiopian highlands. Remote Sensing 5: 2411-2435.

Meze-Hausken, E. 2004. Contrasting climate variability and methodological drought with perceived drought and climate change in northern Ethiopia. Climate Research 27: 19–31.

Norman, L. M.; Villarreal, M. L.; Lara-Valencia, F. and Wilson, S. 2012. Mapping socio-environmentally vulnerable populations' access and exposure to ecosystem services at the U.S.-Mexico borderlands. Applied Geography 34: 413–424.

Prakasam, C. 2010. Land use and land cover change detection through remote sensing approach: a case study of Kodaikanal Taluk, Tamil Nadu. International Journal of Geometry and Geoscience 1: 150-158.

Reddy, G. P.O.; Maji A. K.; Srinivas, C. V. and Velayutham, M. 2011. Geomorphological analysis for inventory of degraded lands in a river basin of basaltic terrain using remote sensing and GIS. Journal of Indian Society of Remote Sensing 30: 15-31.

Singh, A. 1989. Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing 10: 989-1003.

Wickham, J. D.; Jones, K. B.; Riitters, K. H.; O'Neill, R. V.; Tankersley, R. D.; Neale, A. C.; Smith, E. R. and Chaloud, D. J. 1999. Characterizing cumulative environmental impacts on mid-Atlantic watersheds. Environmental Management 24: 553-560.

Yadav, J.; Pathak, R. K. and Khan, E. 2013. Analysis of water quality using physicochemical perameters, Satak Reservoir in Khargon District, M.P, India. International Journal of Environmental Sciences 2: 9-11.

Yuan, F.; Sawaya, K. E.; Loeffelholz, B. C. and Bauer, M. E. 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) metropolitan areas by multitemporal Landsat remote sensing. Remote Sensing of Environment 98: 317-328.

Zelealem, T. and Leader-Williams, N. 2005. Indigenous common property resources management in the central highlands of Ethiopia. Human Ecology 33: 539-565.

Zelealem, T.; Leader-Williams, N. and Coulson, T. 2012. Consequences of human land use for an Afro-alpine ecological community in Ethiopia. Conservation Society 10: 209-216.

Received 27 November 2014;
Accepted 11 December 2014