



Land Use and Land Cover Change Detection in Rural Areas of River Lwiro Micro-catchment, Lake Kivu, Democratic Republic of Congo

M. Bagalwa^{1,2*}, J. G. M. Majaliwa¹, F. Kansime¹, S. Bashwira^{2,3}, M. Tenywa¹,
K. Karume^{4,5} and E. Adipala⁶

¹Makerere University, College of Agricultural and Environmental Sciences, P.O.Box 7062, Kampala, Uganda.

²Centre de Recherche en Sciences Naturelles de Lwiro, D. R. Congo.

³Université Catholique de Bukavu, B.P. 285, Bukavu, D. R. Congo.

⁴Observatoire Volcanologique de Goma, Goma, D. R. Congo.

⁵Université Evangélique en Afrique, Faculté d'agronomie et Environnement, B.P. 3323 Bukavu, République Démocratique du Congo.

⁶Regional University Forum for Capacity Building in Agriculture (RUFORUM), Kampala, Uganda.

Authors' contributions:

This work was carried by author MB, it was designed by authors JGMM, SB and EA, literature search was done by authors FK and KK. Images were analyzed by author MB supervised by authors JGMM and MT. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2016/15850

Editor(s):

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Complete Peer review History: <http://sciencedomain.org/review-history/11751>

Original Research Article

Received 22nd December 2014

Accepted 16th July 2015

Published 8th October 2015

ABSTRACT

Land use and land cover change in River Lwiro micro-catchment was assessed for the period 1987-2010 using satellite imagery of Landsat 5 and 7. Images were clustered into four categories: forest, built-up areas, wetland and small scale farmland area; using unsupervised classification approach. The generated land-use and cover layers were ground truthed and the accuracy of

*Corresponding author: Email: mashibagalwa@yahoo.fr;

classification determined. The results show that forest cover has declined by 23%, and wetland area increased by 2%, small scale farmland by less than 1% and the residential areas by 2.3%. The different trends of change indicated that the micro-catchment has been affected by political instability in the region. The possible environmental impacts resulting from these change need to be identified.

Keywords: Land use and land cover; Lwiro watershed; rural area; GIS.

1. INTRODUCTION

Land use and land cover is one of the most important fields of human induced environmental transformation, with an extensive history dating back to antiquity [1,2]. It has emerged as a global phenomenon and perhaps the most significant regional anthropogenic disturbance to the environment especially in the 20th Century. In Africa, dramatic land use and land cover changes now take place within a few decades. Infact, Ademiluyi et al. [3] deduced that, Africa has fastest rate of deforestation in the world and this is as a result of overdependence on primary resources [3]. Also, recent studies of land cover changes in West-Africa showed that agricultural expansion is the most dominant trajectory of land-cover change [4,5] which involves loss of savannas and forests.

In the Democratic Republic of Congo in general and in Lake Kivu basin in particular, the catchment has significantly changed during the past three decades due to rapid population increase [6-9]. Three studies have been recently conducted the in Lake Kivu basin including Muvundja et al. [10], Basnet and Vodacek, [9], which concentrated on the whole basin and Bagalwa et al. [10] who focused on a micro-catchment around Bukavu town. Basnet and Vodacek, [9] showed that significant land cover changes have taken place in the region over the past 25 years as a result of human migration and horizontal expansion of agricultural land. According to Bagalwa et al. [10], urbanization is a major driving factor of change in land use and land cover in the peri-urban area of Bukavu; where a reduction of 73.64% of small-scale farmland and an increase of 61.11% in built-up area was observed.

Lake Kivu basin has also experienced, in the last two decades, political instability and refugee migration due to civil war leading to large-scale land clearance for agriculture, firewood and timber harvesting [11]. Currently, land has been reported to be scarce commodity [12]. The ongoing transformation of land cover and land

use can affect the integrity of existing natural resource system and ecosystem services [13] of the region which is known has a biodiversity hotspot. Some of effects might include variation of hydrological processes in general and sediment load in particularly [13-15]. These effects can also be exacerbated by climate change and variability. Understanding the implications of changes in land use and land cover is a fundamental part of sustainable land planning and development [16,17].

Assessing land use and land cover change requires the use of geographical information systems (GIS) and remote sensing. These techniques are based on digital change detection on multi-temporal and multi- spectral remotely sensed data as a means to understanding landscape dynamics, detect, identify, map, and monitor differences in land use and land cover patterns over time, irrespective of the causal factors [18-22].

The objective of this study is the identification and quantification of land use and land cover changes in the Lwiro river micro-catchment from 1987 to 2001 and 2001 to 2010 and to calculate the deforestation rate in the region. The rationale for using these dates stem from the fact that it was within these periods that major change such as migration of population from rural to urban areas and massive fluxes of refugees from Rwanda into Democratic Republic of Congo occurred. This study is important to evaluate effects of natural and human activities in the rural region where political instability happened and to inform the regional leaders on conservation efforts needed.

2. MATERIALS AND METHODS

2.1 Study Area

The Lwiro micro-catchment is located on the eastern flank of Lake Kivu, between latitude 2°15' and 2°30' South and longitudes 28°45' and 28°55' east. Its headwaters are the Kahuzi-Biega National Park mountain region, at an altitude of

2000 m. River Lwiro micro-catchment covers Landsat Worldwide Reference System (WRS-2) Path 173 and Row 62. The 84 km² river basin is bordered on the east by Lake Kivu and on the west by the Kahuzi mountain forest (Fig. 1). The micro-catchment is dominated by steep (<3%) hilly topography underlain by sedimentary sandstones and siltstones soils are predominately volcanic where volcanic ash deposits are easily eroded. Its geology is dominated by Precambrian metamorphosed sediments (metamorphic rocks) and Proterozoic platform sediments [23]. The climate is tropical with bimodal rainfall distribution. The dry season spans from June to August and the rainy season from September to May. Annual rainfall is about 1500 mm [24,25]. About 70% of the land is used for agriculture and 10% for irrigated sugar cane field located in the swamp area [26]. Vegetation is dominated by cultivated savanna which replaced the original forest of *Albizia grandibracteata* [27]. Most of the Lwiro river micro-catchment area is characterized by cropland with scarce woodlands and forested highlands. The main croplands consist of maize, beans, cassava and potato. Besides the cultivated lands, the main land cover types are grasslands, marshland and forest with patches of shrubs, eucalyptus woods and trees. Demographic pressure (more than 350 habitats per square kilometer) threatens the natural environment because of the growing logging and cultivation activities [28,29]. The region experienced fluxes of refugees resulting from the Rwandan civil war in 1994 and the Congolese civil war in 1996–2010 [10,30,31]. This micro-catchment covers 4 localities namely Irhambi/Katana, Bugorhe, Luhahi and Bushumba in the territory of Kabare, province of South-Kivu, Democratic Republic of Congo.

To detect changes in land use and land cover at least two time period data sets are required [32]. In this study, land use and land cover changes and forest loss were assessed using landsat TM/ETM images (1987, 2001 and 2010) of 30 x 30 m spatial resolution obtained from the Google Earth Image domain. All the images chosen were limited to dry season months to minimize seasonal effects [9,33]. The year 1987 shows the state of ecological system at the time of instability in the region as described in the previous paragraph while, the year 2001 is chosen as an intermediate point to distinguish the immediate effects of refugee and their movements in the region and the year 2010 is the end of civil war in the Lwiro micro-catchment.

These images were clustered using ILWIS 3.3 version using unsupervised classification [32,34,35]. The classification used in this study followed the classification proposed by Anderson et al. [36], and because of mixed classes in this area, four broad classes were considered for purposes of simplicity including: forest cover, cultivated/small scale farmland, wetland area and settlements/built-up area (Table 1). The classes were identifiable based on the character of the study area physiographic, the resolution (30 x 30 m) of the images used and the availability of ancillary information. The clustered layers were used as preliminary maps and were validated during field work. During the July 2013 field campaign, the major land-use and cover of the micro-catchment namely native forest, tree plantation, grassland, wetland, cultivated area and built-up area were geo-referenced. A total of 108 GPS points were obtained. This information was used to compute the classification accuracy and produce the final land-use and cover maps. In addition, village elders were consulted as key informants in order to reconstruct the 1987 and 2001 land-use/cover maps.

Following the classification of imagery from the individual years, a multi-date post-classification comparison change detection algorithm was used to determine changes in land cover in three intervals, 1987–2001, 2001–2010, and 1987–2010. The preliminary maps were validated and adjusted based on ground truthed data. The change rates of single land use and land cover types were determined according to Peng et al., [37] procedures, where, regressions were used to determine the trend of all the land use and land cover types for different period of time. A systematic way of analysis for land use and land cover change of a period is to compute the total area for the different land use classes for the different duration and to compare the two maps. The flowchart of different step of analysis is presented in Fig. 2.

The rate of change for each type of land use and land cover class during the period of 1987 to 2010 was calculated by applying the formula [38]:

$$dn = \left[\frac{S2}{S1} \right]^{1/n} - 1$$

Where

dn = rate of change

S2 = land cover in time period two

S1 = land cover class in time period one
n = number of years between time periods

This formula is a standardized indicator for environmental monitoring.

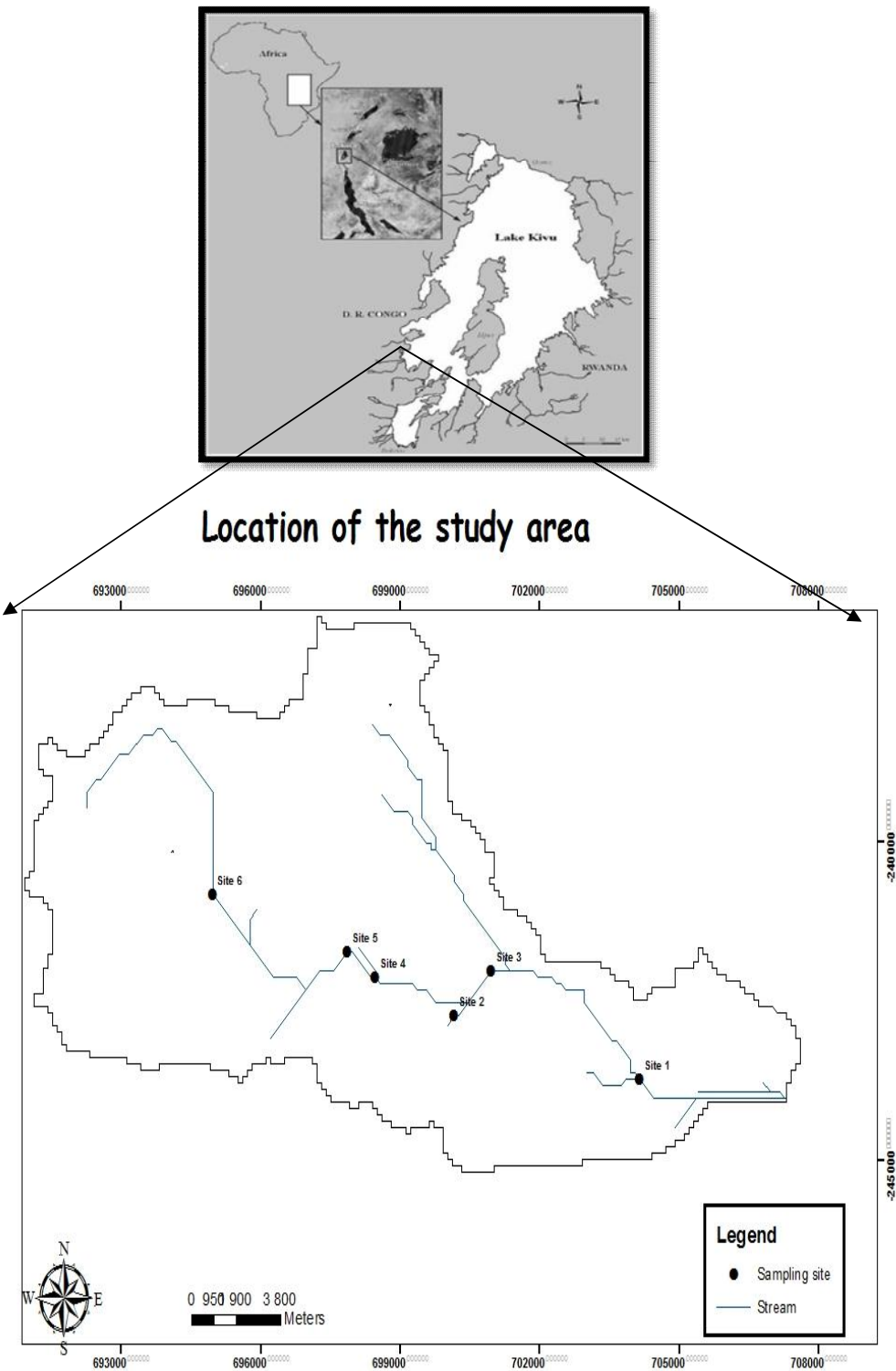
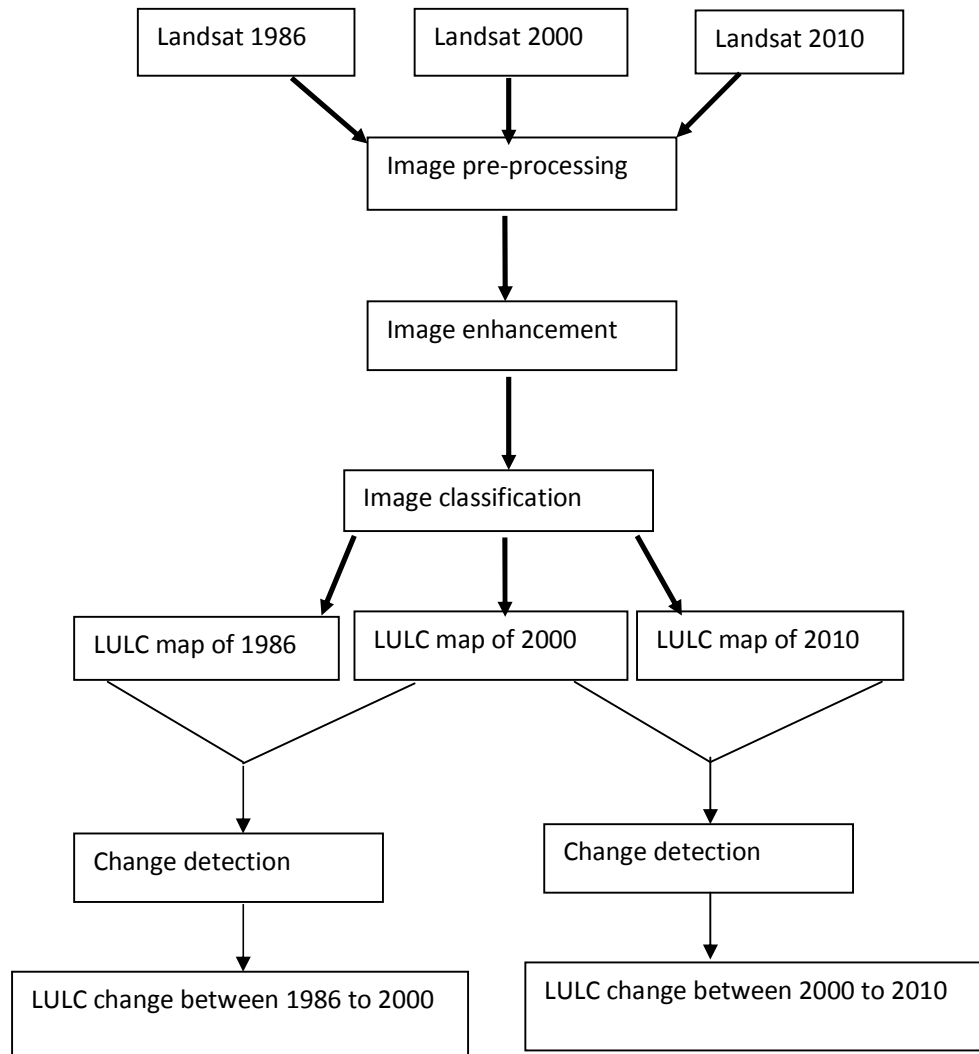


Fig. 1. River Lwiro micro-catchment, Lake Kivu basin

Table 1. Land cover classification scheme in Lwiro micro-catchment

Land cover class	Description
Forest cover	These are areas comprising of deciduous forest land, evergreen forest land, mixed forest land, shrubs, woodland vegetation, primary and secondary forest, scattered tree plants like <i>Acacia</i> , <i>Ficus</i> and <i>Eucalyptus</i> plantation,
Cultivated/small scale farmland	This comprised of areas under continuous cultivation where the plots were covered by mixed cropping such as maize, beans with cassava and sweet potatoes and large scale banana and coffee growing
Wetland area	These are designated areas which are shallow seasonally or permanently water logged and normally support hydrophytic vegetation. This class comprised of <i>Papyrus</i> , <i>Phragmites</i> , <i>Pistia</i> , <i>Typha</i> , <i>Cyperus</i> and large scale sugar cane
Settlements/built-up area	Residential, commercial services, built-up area

**Fig. 2. Land use and land cover change analysis**

3. RESULTS

3.1 Magnitude of Land Use/Land Cover Changes

The results show small scale farmland (50.74%) was the dominant land-use/cover in 1987. It was followed by forest (33.91%) wetland (8.80%) and then built up areas (6.55%). Fig. 2 indicates that there has been a decrease in the forest areas and the increase in small scale farmland over the past two decades. In 2001, small scale farmland (45.77%) and forest and wetland (31.49%) were the most dominant land-use and cover. Deforested areas became wetland and built up area. In 2010, forest cover was reduced to cover

only (5.36%) of the micro-catchment, wetland area was also reduced to cover only 17.12% of the micro-catchment. The rest of the land was used as built-up area (13.87%) and small scale farmland (63.65%). The portion of each land use and land cover class is shown in Fig. 3.

The changes observed in the forest and small scale farmland was due to demographic pressure associated with the presence of the refugee both internal and external and high demand of wood and food. In general, during the twenty three years period the forest land decreased by 84.2% whereas the small scale farmland increased by 25.4%. Table 2 shows the area coverage of each land use/cover class in the three different years.

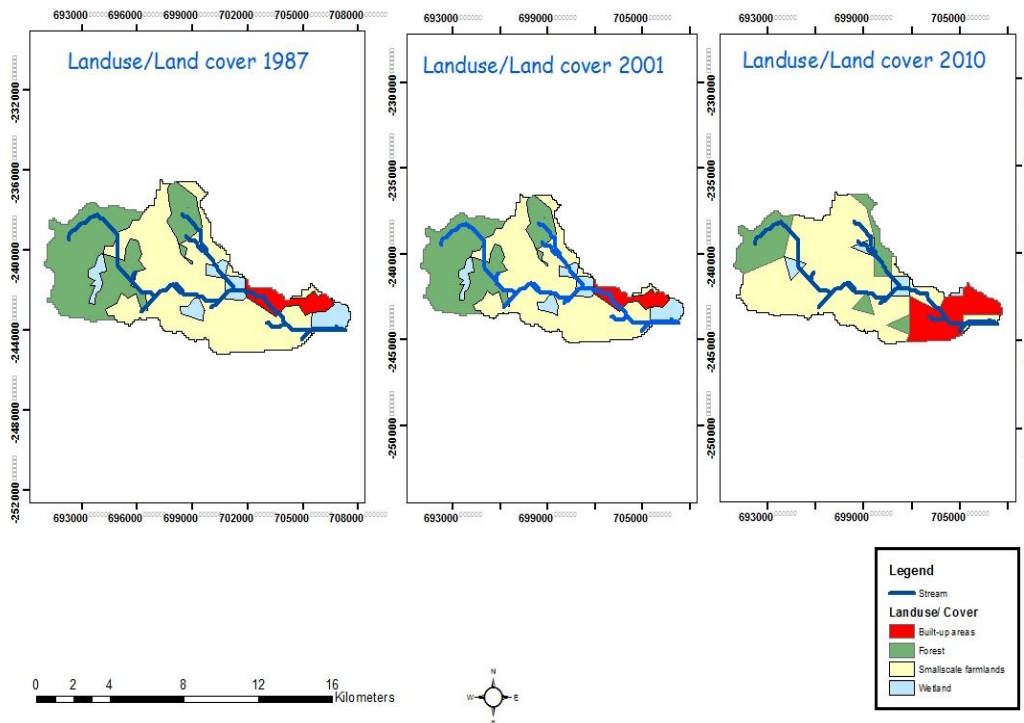


Fig. 3. Land use and Land cover maps in Lwiro micro-catchment 1987, 2001 and 2010

Table 2. Percentage of change in land use and land cover types and deforestation rates in River Lwiro micro-catchment

Classes	Year 1987		Year 2001		Year 2010		Relative change 1987 – 2010
	Area (km ²)	%	Area (km ²)	%	Area (km ²)	%	
Forest	28.49	33.91	9.54	11.35	4.50	5.36	-84.20
Wetland	7.39	8.80	26.45	31.49	14.38	17.12	94.59
Small scale farmland	42.62	50.74	38.45	45.77	53.47	63.65	25.46
Built-up area	5.50	6.55	9.57	11.39	11.65	13.87	111.82

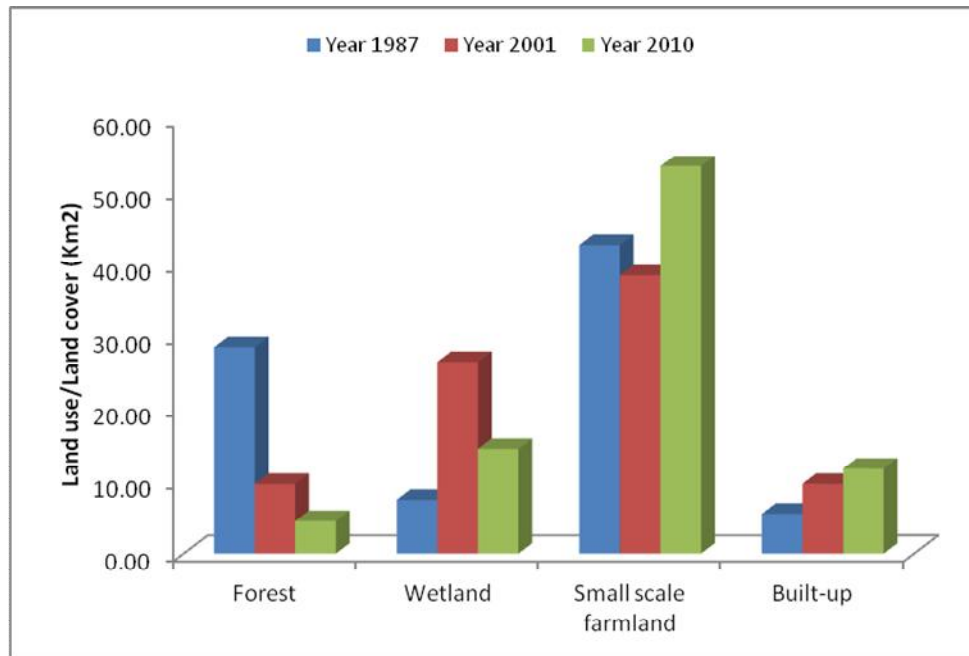


Fig. 4. Change in land use and land cover between 1987 and 2010 in the Lwiro micro-catchment

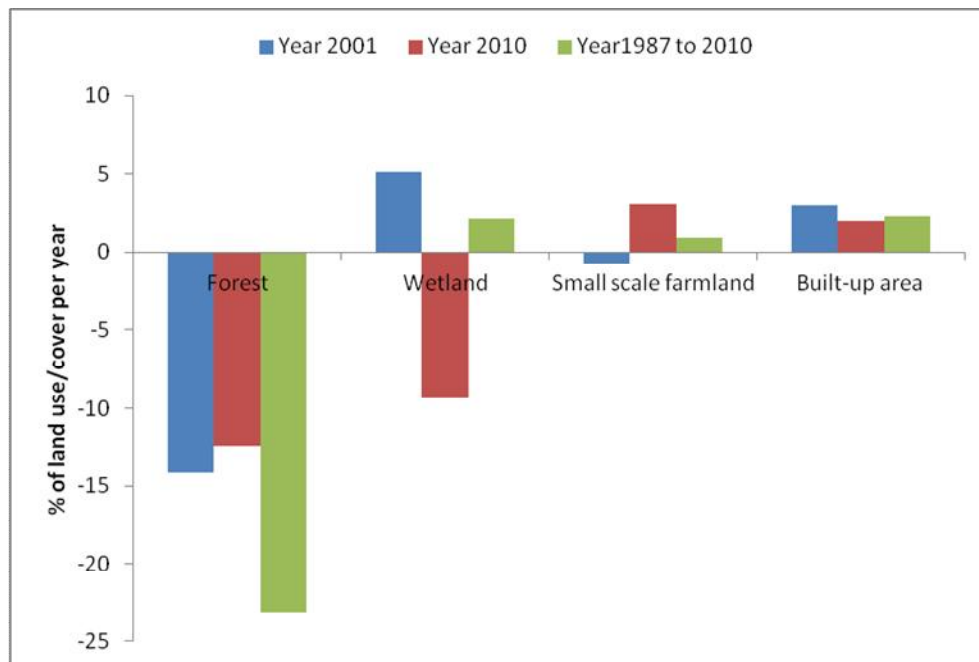


Fig. 5. Dynamics of land use and land cover in River Lwiro micro-catchment

The rate of deforestation between the period 1987-2001 and 2001-2010 were of 7.5% and 8.01%; respectively.

4. DISCUSSION

Land use and land cover change in Lwiro micro-catchment is a result of several factors including

the political instability which prevailed in the eastern DRC and Rwanda during the study period. During the year 1994, millions of refugee found their way into rural area of eastern DRC

including villages in Lwiro micro-catchment. Trees were cut for firewood, charcoal production and timber. The same phenomenon was repeated with the second war of liberation of DRC. This time thousands of families were internally displaced because of the insecurity which characterized the location far from big towns [9,31]. The only difference between the two periods is that during the wave of Rwandese refugees more low land forested areas were cleared for timber and firewood explaining the relative increment of the acreage of wetland in 2001. A big portion of the cleared low land forested areas in 2001 have been converted into agricultural land in 2010 by internally displaced people and the locals. As timber is becoming more lucrative even upland forested areas were cut by the communities and the land converted to agricultural land. This is in line with Mertens and Lambin [39] and Agrawal [40] observations in several tropical countries. These changes could have impacted on the environment particularly on water quality deterioration in the micro-catchment as observed by Bagalwa [24].

5. CONCLUSIONS

The river Lwiro micro-catchment was found to have undergone severe land use and land cover change as a result of human migration (Rwandese refugee and civil war in Democratic Republic of Congo) and subsequent subsistence farming. The forests decreased by 23%, while the wetlands increased by about 2%, small scale farmland 1% and in Built-up areas 2.3% increases were observed. Deforestation rate in the micro-catchment was average 7.8% per year. The quantification of land use and land cover changes of River Lwiro micro-catchment area is very useful for environmental management groups, policymakers and for public to better understand the drivers behind land use/cover change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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