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Study of land use/cover dynamics around forest ecosystems of Kabare and Idjwi areas in Democratic Republic of Congo using GIS and remote sensing

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Abstract

Deforestation in the Democratic Republic of Congo becomes an important problem and causes loss of biodiversity and degradation of many ecosystems. Among this problem, many strategies are used such as reforestation, use of stoves to reduce firewood cut. This study analyzes the dynamic of land use/cover change in forest ecosystems of Kabare and Idjwi over a period of 29 years. Remote sensing was used in GIS to detect change from 1986 to 2015. The results show an increasing of the area in woodlots about 8.48 % in 1986 to 8.79 % in 2015, tropical grasslands from 0.78% to 0.84%, farmlands to 29.99% to 31.94% and settlements from 0.03% to 1.29%. Other classes decreased such as dense forests (14.12% to 10.76%) and water (46.59% to 46.38%). The matrices of change detection show that the area has been changing from one land use to another. The increasing was observed in agricultural area and settlements area from 1986 to 2015. There is the need to take critical measures to regulate land use/cover and conserve the environment not only in this area of study but also whole forest ecosystems in DRC eastern.

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Introduction

Land is a vital natural resource that supports people's lives and development, especially since its use is a fundamental factor in any human activity (Diyer *et al.*, 2013). Generally, land use is any form of human activity on the earth with the intention of benefiting on the earth's resources. Central Africa possesses the world's second largest tropical rainforest which are estimated to 2 million square kilometers of the world forest. About these, 1.681 million hectares are tropical forests (Mayaux, 1998). Forests value has become increasingly evident due to the world population. However, tropical forests suffer from changes in land use (Mayaux *et al.*, 2005, Basabose *et al.* 2010). This change is caused by the expansion activities as agriculture, firewood harvesting, mining, urbanization, road construction, which have contributed significantly to deforestation in the tropics, implies the loss of forests (FAO, 2010). According to Olofsson *et al.* (2013), the impact of change in land use/cover affects a wide range of the environmental ecosystem including the atmosphere, hydrology, geomorphology and ecology.

Comparatively to the rate of deforestation varied from 1.1% in Asia to 0.7% in Latin America and in Africa, research conducted in Central Africa especially in the Congo Basin shows a low rate of deforestation compared to the global average of tropical countries (Duveiller *et al.*, 2008). The decrease in deforestation is linked to the increase in reforestation. In tropical countries, there are increasing of reforestation projects in the place were deforestation is done.

In the Democratic Republic of Congo, forests cover 155.5 million hectares over a total area of 2,329,374 Km^2, representing 67% of the national territory. These forests are plentiful with rich and abundant biodiversity among the richest in the world, in terms of species of flora and fauna. This biodiversity represents an ecological and economic potential that has not yet been valued. The vegetation which is the support, is a reservoir of wide areas of vegetation including several types of primary and secondary forest ecosystems than it was in the past. The current trends of evolution of forests ecosystems indicate a degradation or deforestation taking place. The historical deforestation rate has fluctuated between 0.2% and 0.3% in the DRC over the last 20 years, which is relatively low compared to the world average (0.6%) over the same period (de Wasseige *et al.*, 2010). This situation, caused by both natural and human factors, has been exacerbated by a long period of socio-political crisis and war in DRC (Bagalwa *et al.*, 2016) and climate change (Shalukoma *et al.*, 2015). However, deforestation and degradation are not spread similarly over the national territory, and it should be noted that there are hot spots of deforestation, especially on the edge of big cities in the savannah belt (Kinshasa, Lubumbashi, Kananga) and only in the Cuvette (Kisangani, Kindu), in the North of Equateur Province as well as in the Albertine Rift Zone (North and South Kivu, Eastern Province Orientale) (de Wasseige *et al.*, 2010).

The ecosystems of DRC are seriously threatened by the demographic pressure and development needs through activities as intensive agricultural and industrial clearing, unsustainable logging, and so on. Forests are now being exploited unrestrainedly, which Congolese legislation and administration found difficult to contain (Peltier *et al.*, 2010). Although having a multitude of forest ecosystems more identified in the territories of Shabunda, Mwenga, Kalehe and Fizi, the province of South Kivu resulting from the administrative break-up of the former Kivu, has experienced, in the last two decades, growing insecurity as a result of civil war between armed groups, migration of people from rural areas to urban areas and refugee flows from Rwanda to DR Congo, leading to large-scale land clearing for the region for agriculture and the search for firewood. These activities have a significant impact on vegetation cover, with forests constantly undergoing multiple threats and being endangered, leaving wide expanses of grassland and woodland savannahs (Bagalwa *et al.*, 2016). In addition to these causes and factors of deforestation, there is an alarming disproportion between the speed of regeneration of woody species and the excessive consumption of wood in the country both as a source of energy and for construction.

The territories of Shabunda, Mwenga, Kalehe and Fizi still have a significant amount of forests, while forests in other territories are constantly under threat and endangered, leaving vast expanses of grassland and woodlands and bare lands (Defour, 1994; Balagizi, 2015). The island of Idjwi, the largest island of the Democratic Republic of Congo once had a flora rich in both plant and animal species. The vegetation of the island of Idjwi was bushes with stunted bamboos and forest species, wooded areas of *Eucalyptus, Grevillea, Cypressus* managed by the Belgian settlers, but this vegetation is in full disappearance with the high population growth that observed in this island (Troupin, 1985; Iragi *et al.*, 2012).

The overexploitation of land following a high population density in some areas such as Kabare, Walungu, Idjwi, has caused the reduction or even the suppression of the fallow period. In the territories of Kabare and Idjwi specifically, women and children must travel from 5 to 10 km per day to find the wood needed for cooking. This additional burden reduces the time they could devote to other much needed tasks (FAO, 2010).

For many countries in the world, reforestation is a fight against ecological, economic and social obstacles. In South Kivu, in some areas of the province, some local associations have started timidly to initiate small reforestation projects for village communities which unfortunately, do not take ownership of these actions. Studies of land use/cover change have become key components for natural resource management and monitoring of environmental change (Chigbu *et al.*, 2011). Studies in this area are sparse, except the studies of Basnet and Vodacek (2012), through a recent study in the coastal areas of Lake Kivu catchments, showed that changes in vegetation cover were most important in the region over the last 25 years in the region as a result of population growth and the horizontal expansion of farmland. Bagalwa *et al.* (2014) shows that urbanization is a major driver of change in land use/cover around the urban area of Bukavu, where there was a 73.64% reduction in small-scale farmland and an increase of 61.11% in built-up area.

The identification, description and mapping of land use and land cover types are important activities in sustainable natural resource management, to understand how land use/cover affect and interact with the environmental ecosystems. These are unowned in the province of South Kivu and especially in Kabare and Idjwi territories.

Materials and methods

Study area

This study was conducted in two territories of South Kivu Province in the Democratic Republic of Congo, around two forests ecosystems in Kabare and Idjwi whose choice was motivated by agroecological and socio-economic conditions (Fig. 1). The territory of Kabare possesses too much of the natural heritage of Kahuzi-Biega National Park which includes forest species coveted by local populations. It is located between 28° East longitude, 29° West longitude and 2° south latitude. Its relief is dominated by mountains whose highest peaks are: Kahuzi with 3300 m altitude and Biega with 2700 m altitude.

The mean annual air temperature is 22.6°C, the relative humidity varies between 68 and 75% (CRSN-Lwiro climate service, 1973-2008) and the annual rainfall is 1500 mm (Bagalwa and Baluku, 1997). This territory covering an area of 1960km² and a population of 756,558 inhabitants is an average population density of 386 inhabitants / km² (annual report of the administration of the territory, 2015). The soil of Kabare is by nature volcanic for most of the territory. It is a rich and productive soil but due to overexploitation and exposure to erosion in all its forms (water and wind), it has become one of the poorest (Munyuli, 2000).

Idjwi, an island of Lake Kivu lying to the East of the DR Congo, is the largest of all Africa Inter lacustrine. It covers an area of 680 km² or 1/9 of the entire lake. It is located between latitude 1°59 'and 2°28' South and longitude 29°05' and 28°26' East following the extension in the axial zone of the lake. Idjwi remains dominated by mountainous terrain including the Muganzo mountains in the center of the North (1,829

m above sea level) and especially Nyamusisi in the center of the island, the highest peak at 2300m altitude. Its population is estimated at 252 000 inhabitants with a density of 812 inhabitants/km² (Report of the Territory of Idjwi, 2015).

In the great forest massif of the island, the Nyamusisi forest was home to species such as *Symphonia globulifera* (a characteristic species), *Macaranga monanda, Harungana arborea Harungana montana,* and *Parinari excelsa,* in full disappearance.

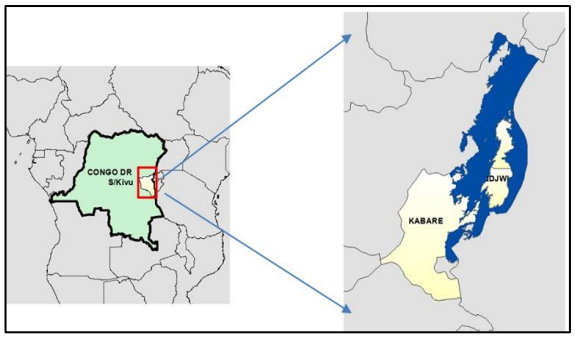

Fig. 1. Map of study area (Idjwi and Kabare region).

Methods

Remote sensing has been used to identify and demonstrate the evolution of land cover over time. Land use data were generated from Landsat TM/ETM satellite images taken for three periods (1986, 2005 and 2015) over a 29 years period analyzed using ArcGIS 10.3.1 software. Satellite images were downloaded from the US Geological Survey (USGS) Global Viewer. Supervised classification procedures have been applied. The type of supervised classification used was the Maximum Likelihood Classification. Variations in land use/cover were analyzed using descriptive statistics. The rate of change was found using Microsoft Excel.

To determine the magnitude and trends of land use/cover changes, Landsat TM/ETM/OLI satellite images with or without cloud from 1986, 2005 and 2015 were used with a spatial resolution of 30m X 30m for the path and rows of scenes covering the study area (Table 1).

Table 1. Landsat types of images use in land use/cover classification in the study area.

Images Types	Spatial Resolution	Acquisition Date	Source	Path and Row (x, y)
Landsat TM 4-5	30m x 30m	19/07/1986	USGS	171 and 61
Landsat L7 ETM	30m x 30m	15/07/2005	USGS	171 and 61
Landsat L7 ETM+	30m x 30m	27/07/2015	USGS	171 and 61

Six land use/cover classes were selected to classify the satellites images. The classes include dense forests, woodlots, tropical grassland, farmland, settlements and water (Table 2).

Table 2. Description of land use/cover classes from classified images.

Land use/cover types	Description
Dense Forests	Dense collection of trees covering relatively a large area, Natural rainforest with many species of plants and animals
Woodlots	An area of land used for the growing of trees, regarded as a source of wood and firewood gathering
Tropical grasslands	An area dominated by grass or grass-like vegetation
Farmlands	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 coffeeg rowing
Settlements	Residential, commercial services, built-up area
Lake	A large, landlocked stretch of water.

Results and discussion

Land use/cover classification

Land use/cover changes each year in our study area is present in the Fig. 2 below. The classification of images shows that in 1986, water (46.59%), farmlands (29.99%), dense forests (14.12%) and woodlots (8.48%) were the most predominant types in land use/cover; whereas tropical grasslands (0.78%) and settlement (0.03%) were lower than other types. In 2005, water (46.54%), farmlands

(34.69%), dense forests (11.75%) and woodlots (6.29%) remained the most predominant types of land use/cover, followed by tropical grassland (0.47%) and settlement (0.27%). However, there were decrease in land use/cover types of dense forests, woodlots, tropical grasslands and water in this period, but farmlands and settlement were increased (Table 3). In 2015, a significant change occurred in this area of study, where settlement increases (1.29%). In fact, water (46.38%), farmlands (31.94%), dense forests (10.76%) and woodlots (8.79%) remained predominant types in land use/cover, but also tropical grasslands indicate a change (0.84%) (Table3). Water decrease (0.22%), generally changed in farmlands, because it is pushed away by the population using soil and naturally by flood.

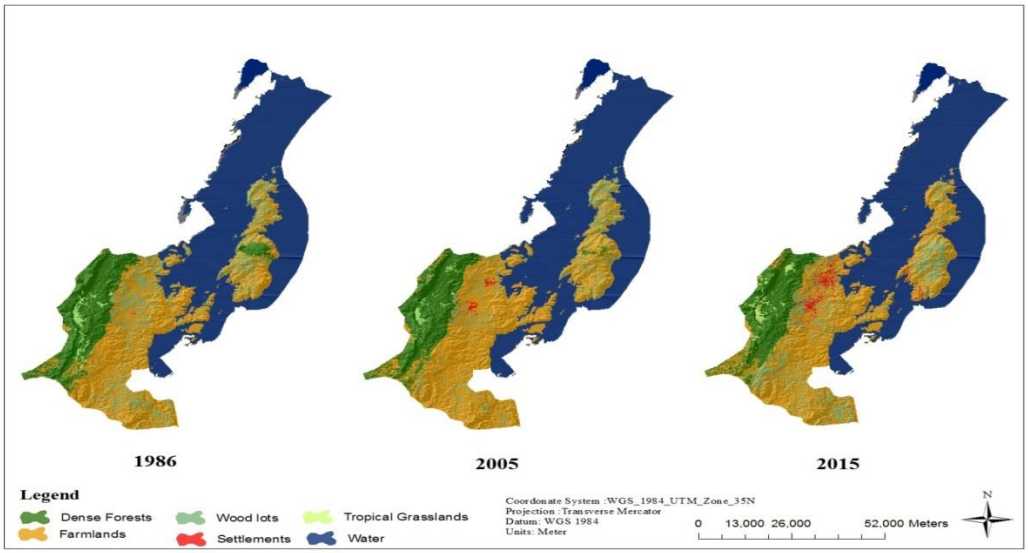

Fig. 2. Land use/cover Map for years 1986, 2005 and 2015.

The most loss of dense forests cover from 1986 to 2015 was clear and apparent in Idjwi side due to the expansion of anthropogenic activities like agriculture and firewood harvesting (FAO, 2010). In Kabare side, the corridor of Kahuzi-Biega National Park was likewise affected and transformed in farmlands and woodlots. In spite of the loss of dense forests, woodlots increased due obviously to reforestation activities in these regions. The statistics land use/cover distribution for each year as derived from the maps are presented in table 3 below.

Table 3. Percentage of land area for each class in 1986, 2005 and 2015.

Categories	1986		2005		2015	
	(Km²)	%	(Km²)	%	(Km²)	%
Dense Forests	402.945	14.121	335.151	11.745	307.157	10.764
Woodlots	242.094	8.484	179.562	6.292	250.725	8.786
Tropical Grasslands	22.293	0.781	13.325	0.467	24.080	0.844
Farmlands	855.895	29.994	989.799	34.686	911.301	31.935
Settlements	0.795	0.028	7.656	0.268	36.902	1.293
Water	1329.576	46.593	1328.104	46.541	1323.433	46.378
Total	2853.598	100	2853.598	100	2853.598	100

The following Fig. shows the trend of land use/cover change from 1986 to 2015.

This Fig. demonstrates that, from 1986 to 2015, farmlands increased (1.94%), followed by the settlement (1.27%) and woodlots (0.32%). As well as tropical grassland increased (0.06%), dense forests decrease radically (3.36%). Bagalwa *et al.*, (2016) indicate that, increasing of tropical grassland is due to immigration of refugees in 1994 and Berry (2008) express that entry of refugees' influx and had impact on the forest resources. Kizza *et al.*, (2017) show that, cultivated land or farmlands and settlement areas increase in both temporally, because agricultural activities increase due to population density increase through immigration and increasing wealth resulting from livestock keeping at the expense of other land

cover types such as forests and woodlots. Ngalande (2002), Mbonile *et al.*, (2003) and Noe *et al.*, (2003) confirm that agricultural expansion is among the reported activities, which have significant effect on natural vegetation.

Kizza *et al.* (2017) conclude that, increase in population size leads to demand for more resources and area for cultivation which has an implication on settlements expansion. In this area, people do not practice birth control family planning, in that case, disturbance of resources is observed.

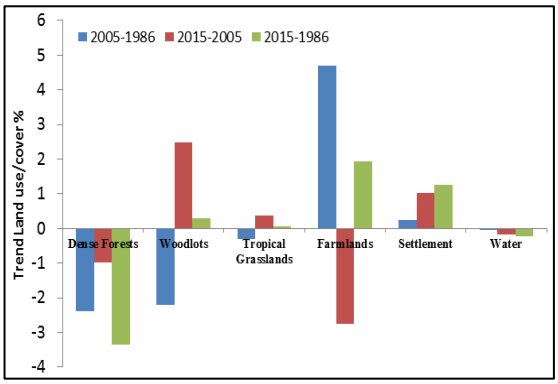

Fig. 3. Trend of land use/cover change during 1986-2005, 2005-2015 and 2005-2015 periods.

Change detection and matrix of land use/cover change

An essential aspect of change detection is to determine what land use type is actually changing to what other land use type. Such information will make know both the desirable and undesirable changes and classes that are not changing overtime. The change detection between 1986 and 2005 is presented in the table 4. This cross-tabulation matrix shows the nature of change of different land use/cover classes. Out of the 402.945km² that was dense forests area in 1986, 309.348km² was still forest area in 2005 but 78.600km² was converted into farmlands, 9.958km² was converted into woodlots and 4.999 km² was converted into tropical grasslands. Generally, forests are challenged by human activities such as agriculture and firewood harvesting (FAO, 2010). At the same period (1986-2005), the decrease of dense forests, was mainly from tropical grassland (11.814km²), farmlands (10.758km²) and woodlots (3.231km²). For Woodlots out of 242.094km² in 1986 about 179.562km² was converted in 2005 to farmlands. The result shows that, settlements increased from 0.795 km² to 7.656km².

Table 4. Change detection matrix between 1986 and 2005 (Km²).

		Change Detection 2005						
		Dense Forests	Woodlots	Tropical Grasslands	Farmlands	Settlements	Water	Total
Change detection 1986	Dense Forests	309.348	9.958	4.999	78.600	0.041	0.000	402.945
	Woodlots	3.231	78.945	0.139	156.516	2.968	0.296	242.094
	Tropical Grasslands	11.814	0.285	7.832	2.362	0.000	0.000	22.293
	Farmlands	10.758	80.575	0.351	738.403	4.210	21.597	855.895
	Settlements	0.000	0.032	0.000	0.371	0.392	0.000	0.795
	Water	0.000	9.766	0.004	13.548	0.044	1306.213	1329.576
	Total	335.151	179.562	13.325	989.799	7.656	1328.106	2853.598

The class which settlements mainly replaced in 2005 was farmlands (4.210km²). In this period farmlands increased significantly from 855.895km² to 989.799km² but only 738.403km² was still farmlands area in 2005. Water class retained only 1306.213km² of the total 1329.576km² in 1986. It was reduced to 1328.106 km² and mainly replaced by farmlands 2005 (Table 4). Tropical grasslands decrease from 1986 to 2005, but only 7.832km² was still grasslands area in 2005, it was transformed in dense forests (4.999km²). These observations are similar to findings in other area in the development countries. Population growth and search of cultivated areas are affecting others land use/cover classes (Bagalwa *et al.*, 2016, Tiwari and Sexena, 2011). The change detection occurring during the period of 2005 to 2015 is present in table 5 below.

Table 5. Change detection matrix between 2005 and 2015 (Km²).

		Change Detection 2015						
		Dense Forests	Woodlots	Tropical Grasslands	Farmlands	Settlements	Water	Total
Change detection 2005	Dense Forests	280.092	7.059	13.888	34.098	0.013	0.000	335.151
	Woodlots	2.361	68.663	0.272	100.286	4.641	3.338	179.562
	Tropical Grasslands	3.830	0.438	8.592	0.459	0.006	0.000	13.325
	Farmlands	20.831	169.693	1.327	766.329	27.716	3.903	989.799
	Settlements	0.043	4.821	0.000	2.009	0.783	0.000	7.656
	Water	0.000	0.050	0.000	8.119	3.743	1316.192	1328.104
	Total	307.157	250.725	24.080	911.301	36.902	1323.433	2853.597

The cross-tabulation present in the table 5 shows the same trend of matrix from 2005 to 2015. This one shows the increasing of woodlots, tropical grasslands and settlements, rather than farmlands, dense forests and water classes decrease during that period. Out of 179.562km² of woodlots in 2005, 68.663km² was still woodlots area into 2015.

About 169.693 km² was converted into farmlands, 4.821km² into settlements, and 7.059km² into dense forests. Thus, out of 989.799km² of farmlands into 2005, only 766.329km² was still farmlands area in 2015. Around 100.286 km² was converted in woodlots, 2.009km² into settlements, 34.098km² into dense forests, and 8.119km² into water. The increasing of settlements area in 2015 is observed by farmlands, woodlots and water. The woodlots were constituted by *Maesopsus eminii, Grevilea robusta, Eucalyptus* sp, *Cedrela odorata, Cypressus lucitanica, Podocarpus uscembarens, Marcamia lutea, Pinus patula, Cassia spectabilis, Terminalia chebula, Erithrina abyssinica, Newtonia buchanani, Bridelia micrantha,* etc. The cross tabulation for 1986 to 2015, the change detection is present in table 6.

Table 6. Change detection matrix between 1896 and 2015 (Km²).

		Change Detection 2015						
		Dense Forests	Woodlots	Tropical Grasslands	Farmlands	Settlements	Water	Total
Change detection 1986	Dense Forests	294.720	26.723	15.522	65.834	0.146	0.000	402.945
	Woodlots	2.779	79.677	0.214	147.683	11.654	0.087	242.094
	Tropical Grasslands	6.388	0.597	7.941	7.366	0.001	0.000	22.293
	Farmlands	3.263	143.233	0.396	664.860	24.728	19.414	855.895
	Settlements	0.007	0.215	0.001	0.298	0.190	0.085	0.795
	water	0.000	0.280	0.006	25.260	0.184	1303.846	1329.576
	Total	307.157	250.725	24.080	911.301	36.902	1323.432	2853.598

This table shows types of land use/cover which change each to another from 1986 to 2015. Therefore, the map view shows four different categories of land use/cover, which have a significant impact on environmental conservation. From 1986 to 2015 the farmlands area decreases significantly for the settlements area.

This situation is due to the overpopulation observed in the study area. People transform agricultural land to built-up area and built roads. Also, we observe through the map that, dense forests area changes significantly and clearly to the tropical grasslands and farmlands areas. According to FAO (2010), this change is caused by the expansion of subsistence activities (agriculture and firewood harvesting), mining, urbanization, road constructions, which have contributed significantly to deforestation and implying the loss of forests.

Thus, other part of dense forests had changed in woodlots area, significantly at Idjwi where Nyamusisi

forest lost its biodiversity. In that case, some private organization developed reforestation activity to give access to the population to have firewood, and restore the old vegetation, that is why woodlots are observed in this previous map. Also, the map shows the decreasing of farmlands area changed in woodlots area, due to that initiative of reforestation in the study area. This study elucidates the significance of incorporating Remote Sensing and GIS for change detection study of land cover/land use of an area as it offers crucial information about the spatial distribution as well as the nature of land cover changes. Overall 95% accuracy of the land use/cover maps indicates that the integration of supervised classification of satellite imagery with visual interpretation is an effective method for the documentation of changes in land use/cover of an area.

Conclusion

Land use/cover changes in this study area were qualified using remote sensing technique. In the period of 1986 to 2015, the principal and striking land use/cover are dense forests, woodlots, tropical grasslands, farmlands, settlements and water. Tropical grasslands and water have not significantly changed from 1986 to 2015. But dense forests, woodlots, farmlands and settlement have changed significantly in that period. Although Idjwi territory lost completely its dense forests from 1986 to 2015, Kabare territory lost its dense forests too; obviously through the corridor of Kahuzi-Biega National Park. There was a significant increasing observation in agricultural area and built-up area from the period of study. Therefore, there is the need to take critical measures to regulate land use/cover and to conserve the environment not only in this area of study but also the whole forest ecosystem.

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