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Analysis of Land Cover Changes Occurred in Brazzaville between 2001 and 2012 Using Landsat Images

Kempena Adolphe[1], Boudzoumou Florent[1], Nganga Dominique[2]

[1]Department of geology, Faculty of sciences, University Marien Ngouabi, Brazzaville-Congo

[2]Department of physic, Faculty of sciences, University Marien Ngouabi, Brazzaville-Congo

Abstract: ***The analysis of the land use and land cover changes has a great importance to obtain fundamental information for management and land use planning at different scales and environmental studies, natural hazards and disasters. An essential tool for pertinent results is satellite images providing on the same scale a greater number of data to assess the land use and land cover changes all over the years. From the comparison of classified Landsat images (TM and ETM+) it was obtained changes occurred between the years 2001 and 2012 for the city of Brazzaville. This research corresponds to the digital image processing and supervised digital classification, where it is shown the significant changes, using the values of observed and expected change between classes. One obtained maps of different kinds of land use and land cover for different periods, which produced a table of the dynamism of land use and land cover.***

Keywords: land use, land cover, supervised digital classification, significant changes, Landsat TM and ETM + image

1. Introduction

Lastly, there has been more concern how land covers are undergoing changes in their status and extent as a result of human activities and natural phenomenon. These changes, among other consequences involved in soil erosion increase water runoff and flooding, causing changes in the biodiversity and alter processes that have consequences on the climate [1]. The detection of changes in land use and land cover has a great importance, an adequate management and land use planning at different scales [2]. The changes produced on the landscape are the result of complex interactions among physical, biological, economic, political and social factors. Considering the influence of human activities on the ground, various causes determine the modification and conversion of kind of land use and land cover in a given area. One is the economic vision in which the changes occur for uses that generate higher returns [3]. Others are motivated by the increasing population and the consequent need for the natural space occupation, goods and services, for the lack of resources, coupled in many cases with an unequal land distribution and poverty.

The landscapes of Brazzaville, with predominant savannah and forests covers, being a region of high population density, in many cases have undergone a rapid conversion of native vegetation introduced by buildings [4]. The reasons for the higher proportion of changes in the landscapes of Brazzaville, though not documented, are social and economic, it is seen that the occupation of steep terrain for the implementation of housing because of financial situation from those who do not have sufficient resources to purchase land on the flats areas or near the city center. However, no studies have been applied to satellite images for the discrimination of the kind of land use and land cover in space and time and therefore there are no statistics on land use changes.

2. Study Area

Brazzaville city is located on the right bank of Congo River which it shares with Kinshasa city. Its extension is about 30 km and has seven neighborhoods as shown in figure 1. In 2008, the report of the National Center for Statistics and Economic Studies (CNSEE) showed that more than one million people live in Brazzaville [5]. The relief of Brazzaville consists of hills, plateaus and plains [6]**.** These plateaus are converted to hills in the area of Nkombo and Massengo located in Talangaï and Mfilou neighborhoods respectively. Some areas of Talangaï and parts of Ouenzé, Moungali, Poto-Poto (figure-1) are located in the plains and are submit to flooding during rainy periods [7]**.** The climate of Brazzaville is kind of "Bas Congo" with a rainy season from October to May and a long dry season from June to September. It has also a slowing down of rainfall between January and February [8, 9]. Brazzaville city is characterized by savannah including typical species of sandy soils. The plateaus contain grove and gallery forests bordering streams [10]. In general, Brazzaville soils are very poor in clay and organic matter [11, 12]. They are called lateritic and classified into four main groups: podzols soils, ferralitic soils, hydromorphic soils and unsophisticated soils [13].

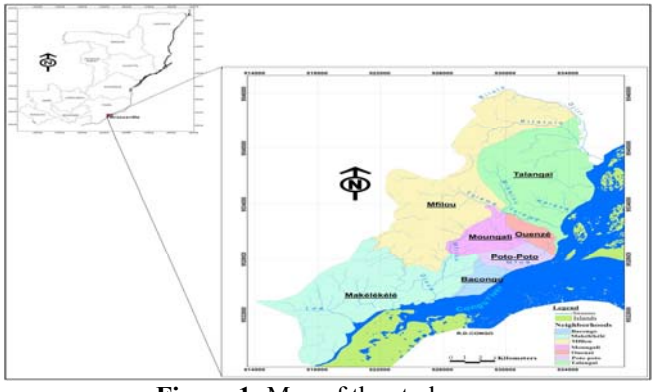

Figure 1: Map of the study area

3. Data and Methodology

The assessment of the dynamism of land use and land cover was done with two types of satellite Landsat images (TM and ETM +) of February 2001, 2006 and 2012 (path 182 row 63) obtained from the Central Africa Forest Observatory. The editing and design of topological thematic layers was necessarily performed using the Arcgis 9.3.1 program. As a secondary source of information, it is used basic maps produced by the National Institute of Cartography and field work information. The methodological model used is based on the techniques of digital processing of satellite images with spatial analysis of georeferrenced thematic information through a Geographic Information System (GIS). As those landsat images were already processed by the Central Africa Forest Observatory (OSFAC), we evaluated the supervised classification of the images based on the study "priority areas for soil conservation in the city of Brazzaville" led by the Ministry of Forestry and Environmental Economics and implemented in 2012. From this classification were generated 5 classes of land use and land cover. The output images showed good thematic approach, a situation which served to differentiate the different vegetables strata, lake and human occupation. The classified and recoded images were converted from raster to vector format automatically. The land use and land cover layers were processed in Arc GIS 9.3.1 with adjustments relating to the study area borders and subsequent edition. The resulting vector layers of thematic maps were subject to analysis for spatial and temporal relations from union and intersection of land use and land cover. The results of this process were analyzed statistically from observed changes in land use and land cover.

4. Results and Discussion

The resulting maps represent the land use and land cover for the city of Brazzaville for the years 2001, 2006 and 2012, taking into account the legend classification system proposed by the CENIAF [14]. The figures 2, 3 and 4 show the spatial distribution of different land uses and land covers for different years in the city of Brazzaville. It is seen that in year 2001 there is a prevalence forests, mostly natural. The built is distributed throughout the city, but less in the Neighborhoods like Makélékélé, Mfilou and Talangaï, which have the largest amount of forest being younger neighborhoods than the others. Lakes are found only in the north east in the vicinity of the river Congo. Savannahs have a greater concentration in the central part of the city and northern Moungali, however there is also the presence of this type of land cover in other Neighborhoods. Bare land is observed only in neighborhoods Moungali, Talangaï and some parts of Makélékélé.

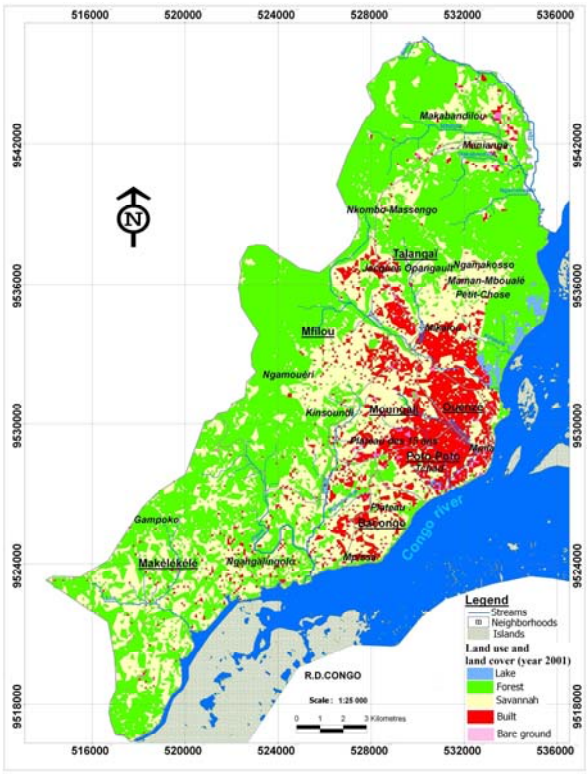

Figure 2: Land use and land cover map (year 2001)

In the year 2006 as shown in the figure 3, Brazzaville city is dominated by a strong red color and violet. That explain how people begin to occupy new spaces for building especially in the youngest neighborhoods like Talangai and Mfilou. With that city evolution, it is clearly that the people have built so much in the time and the new natural spaces have been disturbed and conversed in residential spaces.

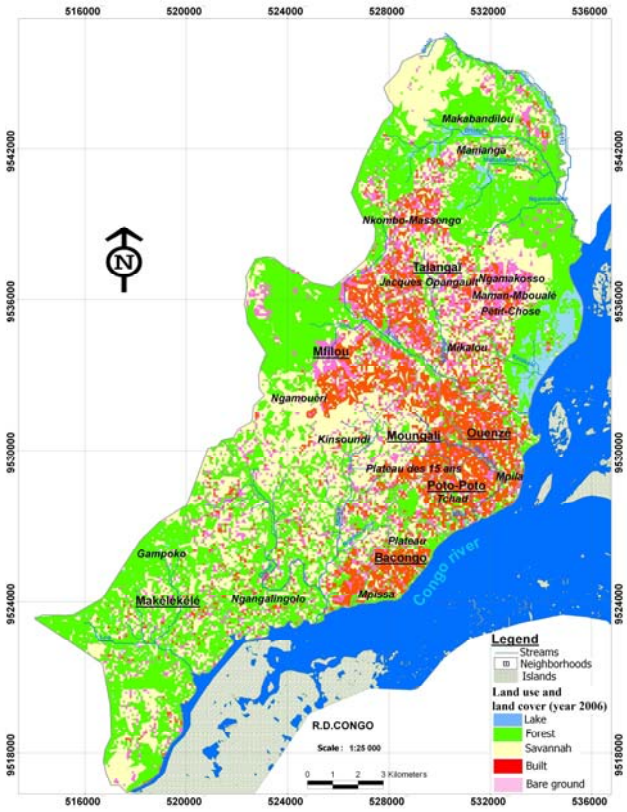

Figure 3: Land use and land cover (year 2006)

The figure 4 shows that in 2012, the study area is dominated by the red and violet color. This time the built and bare land have distributed almost throughout the city, but a higher concentration in the neighborhoods Bacongo Ouenzé, Moungali, Mfilou and thereby Talangaï justifies the growth of the city in the last 11 years. The dense and fragmented natural vegetation is mostly located in the vicinity of areas of greater built concentration, which means that the development of the city is some thing that progressively starts from older neighborhoods to younger neighborhoods. It is possible that this location may obey with the steep slopes aspects of the northern neighborhoods and the distance that separates these neighborhoods with those occupied for housing in the southern part of the city.

The savannahs are distributed throughout the city, but are mainly associated with the existing forests. Lakes are located only in the Ouenzé, Mfilou, Talangaï neighborhoods and areas near the Congo River.

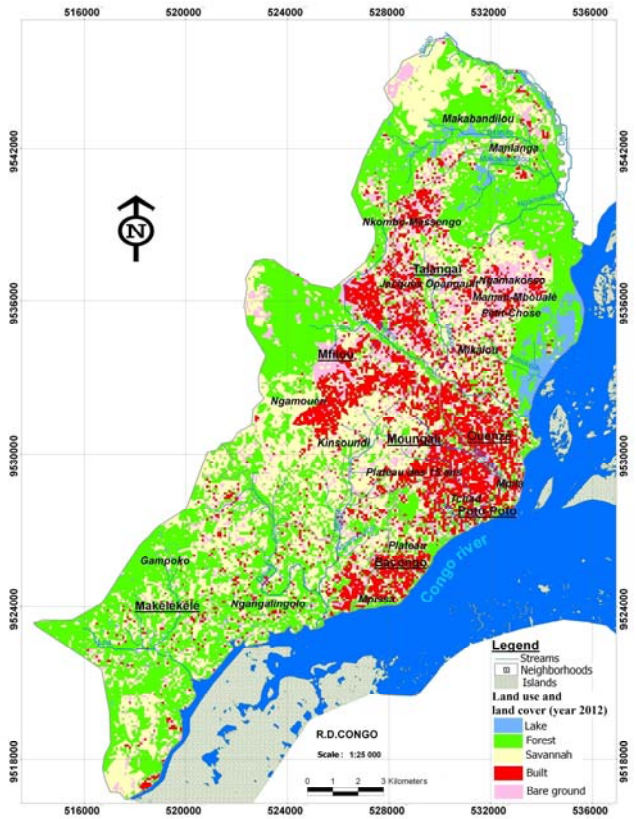

Figure 4: Land use and land cover (year 2012)

4.1 Occupation and Land Use change

After analyzing the land use and land cover for different years, it is important to see the transformation of the environment by human activities in different years as shown in the table 1. With that one can see the dynamism of the land use and land cover for 11 years and how the natural spaces have changed. The table 1 shows the different changes occurred over time for each land use and land cover. The types of land use and land cover in 2001 are lake (0.632%), forest (52.995%), savannah (34.359%), bare ground (0.769%) and built (11.190%). In 2006, the types of land use and land cover are lake (2.77%), forest (41.08%), savannah (32.50%), bare ground (11.01%) and built (12.71%). In 2012, they are lake (2.361%), forest (40.590%), savannah (30.031%), bare ground (12.068%) and built (14.960%).

4.2 Dynamism of land uses and land covers between years 2001 and 2012

The table 1 shows that the area occupied by lake almost doubled between the two periods, from 161.403 ha in 2001 to 679.242 ha in 2012 because lakes are represented by permanent swamp regions, which in 2001 occupied the 0.632% of the area and 2.361% in 2012. Swamps are related to overflowing rivers and flooding by runoff and some located near area with high human activities influence [15, 16]. The forest showed a reduction in area from 52.995% to 40.590% between 2001 and 2012, both savannahs with 34.359% in 2001 and 30.031% in 2012. However, bare land and built respectively increase between 2001 and 2012 from 0.769% to 12.068% and 11.190% to 14.960% respectively. This reduction of forests and savannahs is the concrete evidence of the influence of socioeconomic pressure on the environment. This means that the man transforms vegetation mainly in area of building, public and private infrastructures, this use without regard to geotechnical standards, in other word is irrational since the areas with steep slopes and considered dangerous have been converted into residential spaces. The land use that sowed more change is the human occupation (built and bare land) that experienced a change of -16.04%. This appreciable change is due to housing in young or new neighborhoods of the city, which has caused the urban growth [17, 16]. The land use like the forest with that percentage (-12.41%) shows a significant impact on the runoff behavior. The same occurs in the savannah that with a negative percentage (-3.63%) has also a negative impact on the environment.

Table 1: Land use and land cover, changes occurred between years 2001 and 2012

Types of land use and land cover	Years			Changes occured betwen 2001 and 2012
	2001	2006	2012	% of change
Lake	161.403 ha	706.886 ha	679.242 ha	+2.03%
	0.63%	2.77%	2.36%	
Forest	13529.807 ha	10489.683 ha	10362.745 ha	-12.41%
	53.00%	41.08%	40.59%	
Savannah	8772.068 ha	8297.08 ha	7845.662 ha	-3.63%
	34.36%	32.50 %	30.03%	
Built	2856.885 ha	3243.795 ha	3819.334 ha	+3.77%
	11.19%	12.71 %	14.96%	
Bare ground	196.216 ha	3065.422 ha	3081.010 ha	Type of change -: diminution +: increasing
	0.77%	11.01%	12.07%	
TOTAL in %	99.95%	100.01 %	100%	

5. Conclusion

It shows that the growth of the city depends on the type of land use attributed to the environment. The search of natural space for the population accommodation is the main reason that broadens the city perimeter. The easiest and quickest land uses primarily affect areas easily accessible by the man and then the distant areas. Human pressure in the city of

Brazzaville and its surroundings is the cause of altered environmental balance (figures 5 and 6). The lack of protection in sensitive areas to natural phenomena is the lack of political leaders concern. The importance of the ecological conservation and environmental education should be given to the local people for the conservation of dangerous areas toward natural phenomenon. Within the span of 11 years, land use surrounding the city of Brazzaville was completely passing area considered in the past as dangerous to natural phenomena and could show negative impact when an anthropogenic action on them. The fragility of the areas recognized for their vulnerability to natural events and so threatened, demonstrates the need for more attention from the public and the government. This work highlights the environment changes situation by different land uses and land covers. In the perspective of space-time, the harmful anthropogenic action has changed the environment and the lack of environmental monitoring becomes a situation more difficult to resolve.

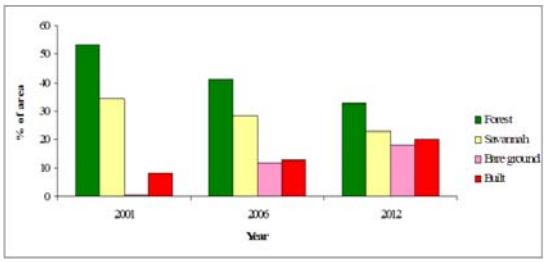

Figure 5: Land use and land cover aspects

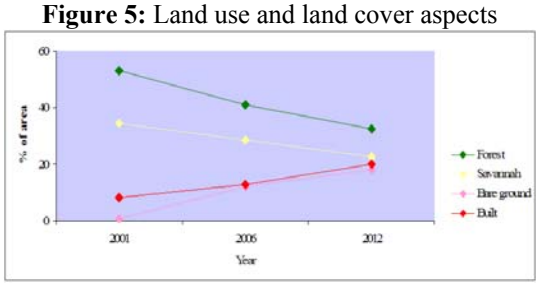

Figure 6: Environnemental changes speed

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Author Profile

Kempena Adolphe, he is Lector on remote sensing and cartography in Departement of Geology, Faculty of Sciences and Technique, University Marien NGOUABI. He is interested for research work in remote sensing, environmental sciences and cartography.

Boudzoumou Florent, he is Lector on tectonic and stratigraphy in Department of Geology, Faculty of Sciences and Technique, University Marien NGOUABI. He is interested for research work in tectonic, stratigraphy and structural geology.

Nganga Dominique, he is Lector on mechanics and physics of the atmosphere, Department of physics, Faculty of Sciences and Technique, University Marien NGOUABI. He is interested for research work in mechanics and the atmosphere pollution.