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Land Cover Dynamics in the Kani Red Bandama Classified Forest (Northern Côte d'Ivoire)

Dr. Konan Kouadio Eugene

Institute of Tropical Geography (IGT), Félix Houphouet BOIGNY University (UFHB)

Head of the Master: Geomatics and Engineering of Environment and Planning (G-IDEA) University Institute of Abidjan (IUA)

01 BP 3439 Abidjan 01

ABSTRACT: Several studies on the disappearance and monitoring of natural resource dynamics on a global scale show a general trend towards the disappearance of natural areas. Protected areas are not immune to this scourge. Thus, this study attempts to analyze the management of protected areas in Côte d' Ivoire through the Kani-red Bandama classified forest. Overall, the study aims to assess the impact of human practices on the resources of this classified forest. As activities, the aim is to characterize the dynamics of land use in the classified forest and to determine the factors of these dynamics. The study is based on satellite images (Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIRS) from 1986, 2001 and 2016, cartographic and socio-demographic data, and field observations. The preferred tools for data processing and analysis are remote sensing and GIS. The results show that natural areas under the effect of human actions are undergoing very advanced degradation. In 15 years, natural areas have given way to agricultural areas which have increased from 1% to more than 30% with an intensification of cashew nut cultivation resulting in the multiplication of cashew nut orchards. The classified forest of Kani red Bandama is under the influence of human activities reflected by the infiltration of agricultural settlers and breeders whose opposing uses of natural resources lead to conflicts.

KEYWORDS: Côte d'Ivoire, dynamics, land cover, Kani classified forest.

INTRODUCTION

The question of the disappearance and degradation of the plant cover of protected areas occupies a central place in the field of research in Côte d'Ivoire. The issues raised by the expansion of agriculture within these spaces are clearly identified through several scientific studies (Konan, 2008; Adon, 2010; Goh, 2015).

Currently, the rare forests still persisting in Côte d'Ivoire are found in classified forests, nature reserves and protected areas. However, these protected areas are influenced by the actions of the riparian populations which each year lead to the disappearance of several thousand hectares of natural areas. Thus over the period from 1969 to 2004, more than 200,000 ha of forests disappeared (BNETD, 2004). Also, in the current perspective of sustainable development and climate change adaptation policies, it is essential to identify and assess the parameters underlying the disappearance of plant cover in order to understand and control future changes, in particular for societal issues on a regional (heritage and economic value) or global scale (carbon stock and emission, biodiversity).

On this basis, the guiding concern underlying this research was as follows: What is the state of conservation of the vegetation cover in the classified forest of Kani-Bandama rouge? Careful consideration of this central question raises the following subsidiary questions: What is the level of land cover and use in the Kani-Bandama Red Forest? What are the explanatory factors for changes in land use in the classified forest of Kani-Bandama rouge?

The central objective of this study is to analyze the characteristics of changes in land use in the classified forest of Kani Bandama rouge.

Specifically, it involves: i) evaluating the dynamics of the vegetation cover of the classified forest by satellite remote sensing over 3 periods; ii) establish the complexity of the multi-criteria system (explanatory factors) responsible for changes in land use and agro-landscape transitions in the classified forest.

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The classified red forest of Kani-Bandama with a theoretical area of 121,088 ha is located in the north of the Ivory Coast (figure 1) straddling the department of Dianra and the department of Kani. This forest has undergone several modifications since its creation in 1937 with the status of ranch with an area of 39,422 ha. In 1939, the area of red Kani-Bandama was changed as well as its status. From range, it became a classified forest in 1939 with the decree of its creation n ° 837SE / F / of March 26, 1939. The present study concerns the eastern part of the classified forest which covers an area of 49,226 ha.

Located in the agroecological zone known as the Sudano-Guinean zone, the classified forest of Kani is characterized by a Sudanese-type climate punctuated by two distinct seasons. A dry season, generally marked by the phenomenon of the harmattan which begins in November and ends in May (Mahop, 1983). Temperatures vary from 25 ° C to 31 ° C with an average of 28 ° C (. The rainy season is between the month of May and the month of August with a rainfall varying between 0 mm of rain in December and 288 mm of rain. in August. The vegetation belongs to the sub-Sudanese savanna. All the savannah formations are present, from the wooded savanna to the grassy savanna. The characteristic forest of the region is the dense dry forest which one finds mainly on the tops of the interfluves and forest galleries.

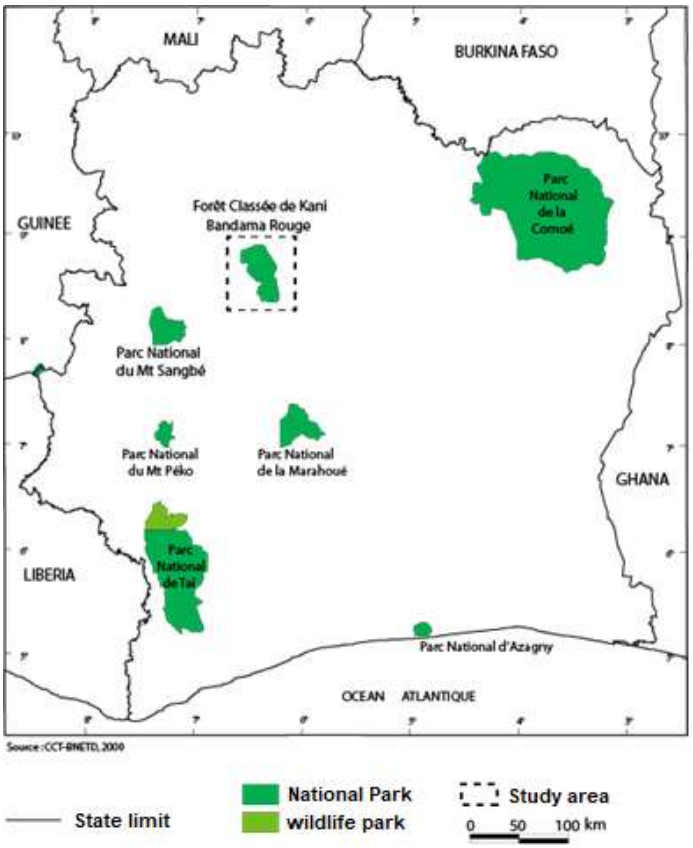


Figure 1: Location of the classified forest of Kani Bandama rouge '(Source: CCT-BNETD, 2000)

METHODS

Data

The conduct of this study relies on hardware, consisting of satellite and cartographic data, as well as software. The field mission was carried out using a GPS for the geolocation of human traces and learning areas for the image classification phase, a digital camera for taking pictures of certain control sites and a dictaphone for recording interviews.

The cartographic and satellite data used consist of a topographic map of the department obtained from SODEFOR, a vegetation map obtained from IRD and six satellite images. These images are composed of two Landsat 5 TM images from 1/7/1986 and 01/14/1986, two Landsat 7 ETM + images from 01/16/2001 and 01/23/2001, and two Landsat 8 images OLI / TIRS of 02/04/2016) and 02/27/2016) all scenes 197-054 and 198-054, downloaded from the USGSGloVis site (http://glovis.usgs.gov/). They were acquired in the dry season, a period of poor cloud cover.

Data collection techniques

In this study, several information gathering techniques were used. These are the documentary research and the field survey.

Documentary research constitutes the first stage of this research work. It allowed to know the state of progress of the work carried out on the theme. Thus scientific articles and reviews, theses, dissertations and various documents have been consulted in libraries and on the internet (google scholar and researche for live).

The survey carried out on the ground allowed for the observation on the ground, and for interviews with the administrative authorities, the heads of land (The Talafolos), herders and farmers.

The field observation consisted in carrying out field surveys in a balanced way in the types of land use using a GPS in order to have an idea of the space occupation of our site study.

Data processing and analysis

The monitoring of ecological dynamics is first analyzed from the point of view of the dynamics of the vegetation cover, using remote sensing methods. Thus, a number of remote sensing techniques are used to reveal changes in the state of the surface (Konan, 2008). To produce land cover maps, two phases are allowed: the image pre-processing phase, the image processing phase, and the use of a Geographic Information System (GIS.

Image pre-processing

Image pre-processing is a set of operations that aim to increase the readability of images to facilitate their interpretation. In this study, it boils down to mosaicking and image contrast enhancement, and the extraction of the study area. It should be noted that the images obtained have already undergone the various corrections (radiometric and atmospheric).

Since the study area was covered by two image scenes (197-54 and 198-54), it was necessary to assemble them before processing through mosaicking. This technique makes it possible to have a single image (Jobin, 2007).

Image processing

The Image Processing Phase comes down to defining land cover classes, mapping land cover by remote sensing and validating the classification (assessment of accuracy).

Definition of land use classes

The definition of these classes was carried out from images resulting from colored compositions which allow good spectral discrimination of ground assignments, favoring the identification of the entities to be mapped on the satellite image. Also, the sites sampled during the field observation were important in locating elements on the images. Thus, a total of 6 classes were retained for the images of 1986 and 2001, and 9 classes for the image of 2016.

Mapping of land use by remote sensing

Remote sensing mapping makes it possible to reproduce the reality contained in the images using the themes. In the present study, the technique used is the supervised or supervised classification which consists of a hierarchy by successive stages or pseudo-supervised hierarchical classification (Fotsing, 2009). The algorithm used in this classification is the maximum likelihood algorithm, which is based on Bayes' rule and makes it possible to calculate for each pixel its probability of belonging to one class rather than another. The pixel is assigned to the class with the highest probability of belonging.

Classification validation (accuracy assessment)

The validation of the classifications was done in two stages:

- Analysis of class separability represents statistical tests to measure the ability of a parameter to discriminate between two different classes
- The confusion matrix is a technique that allows you to compare two classifications: training sites and control sites to produce the confusion matrix. Indeed, the matrix makes it possible to calculate the overall precision (OA: Overall Accuracy) and the Kappa index (K) (Dusseux, 2014). Generally, it is established that classifications with values of K greater than 0.8 are excellent, K between 0.6 and 0.8 are acceptable and K between 0.4 and 0.6 show poor accuracy.

IMPROVED CLASSIFICATION

The raw classification results were subjected to post-classification filtering to clean up the classification image, match it to UMC (Minimum Mapping Unit) requirements, and reduce errors while eliminating single pixels. The UMC adopted to produce the land use map is 0.1 ha in accordance with the new forestry code of Côte d'Ivoire which sets the minimum forest area at 0.1 ha. The methodology adopted for the post-processing can be summed up in two passages: passage of a major convolutional filter of dimension 3 x 3 pixels to reduce noise and a second passage of a sifting filter of a size of 10 pixels, corresponding exactly 0.1 hectares and for all categories. Once the filter was completed, the images were converted to vector and exported to a GIS environment.

Use of a Geographic Information System (GIS)

The data resulting from the processing of the images were exported in a GIS environment to create a database. This database has been strengthened by the addition of cartographic data (localities, roads, hydrographic network and boundaries). GIS can be defined as a computer tool for storing, managing, processing and representing geographic information for the purpose of decision making (Konan, 2008). The use of the database consisted in making query operations on one or more data in the database in order to search for information or to produce new cartographic, graphical or statistical data. Two software programs were used for data processing. This is the Envi 5.1 software for processing satellite images, ArcGis 10.2.2 for GIS applications and cartographic writing.

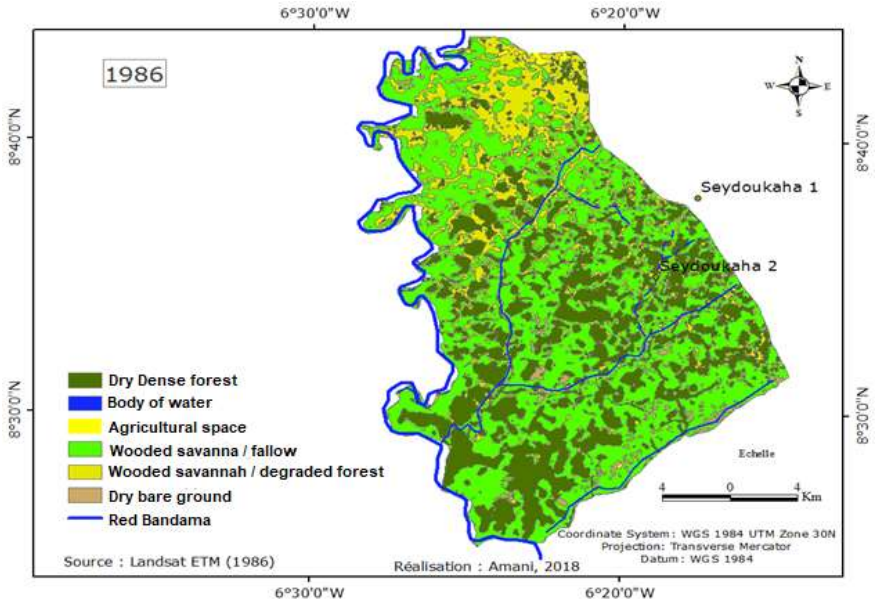
RESULTS

A spatial dynamic of land use marked by the gradual disappearance of natural spaces from 1986 to 2016

The land use maps (Figure 2) and the various statistics (Table 1) make it possible to highlight the spatio-temporal dynamics of socio-ecological surfaces.

With regard to the analysis of land use maps of the classified forest of Kani Bandama rouge (East) from 1986 to 2001, it appears that the distribution of land cover types was marked in 1986 by a dominance of wooded / fallow savannah and dense dry forests which respectively represented 51.7% and 30.3% of the area with a slight presence everywhere in the eastern part of the Red Kani Bandama Classified Forest. Agricultural areas confined to the north of the zone occupy 0.4% of the territory. In 2001, the distribution of land use classes will change. At the level of dense forests, we notice a decrease of 4% of the area. From 30%, the dense dry forest increased by 26%. However, we are seeing an increase in the areas of wooded / fallow savannas and degraded wooded / forest savannas. From 67.7%, these land use classes have increased to 72% due to the increase in degraded and fallow forests that are associated with the savanna classes. Agricultural areas have experienced a significant increase during this time. From 0.4% they went to 1% of the surface.

From 2001 to 2016, the surface of the classified forest of Kani Bandama rouge (East) was transformed into a mosaic of crops and cashew orchards which occupies the north and south-east of the area. In 15 years, the area of dense dry forests has fallen from 26% to 9.85%, ie a decrease of 16.15% in its area. Agricultural areas have gone from 1% to more than 30%. Cashew tree plantations have multiplied during the period from 2001 to 2016 with a coverage rate of 2.54% of the total area of the classified forest. This situation is the result of the massive infiltration of herders and farmers into the classified forest from 2002 onwards following the military political crisis in Côte d'Ivoire.



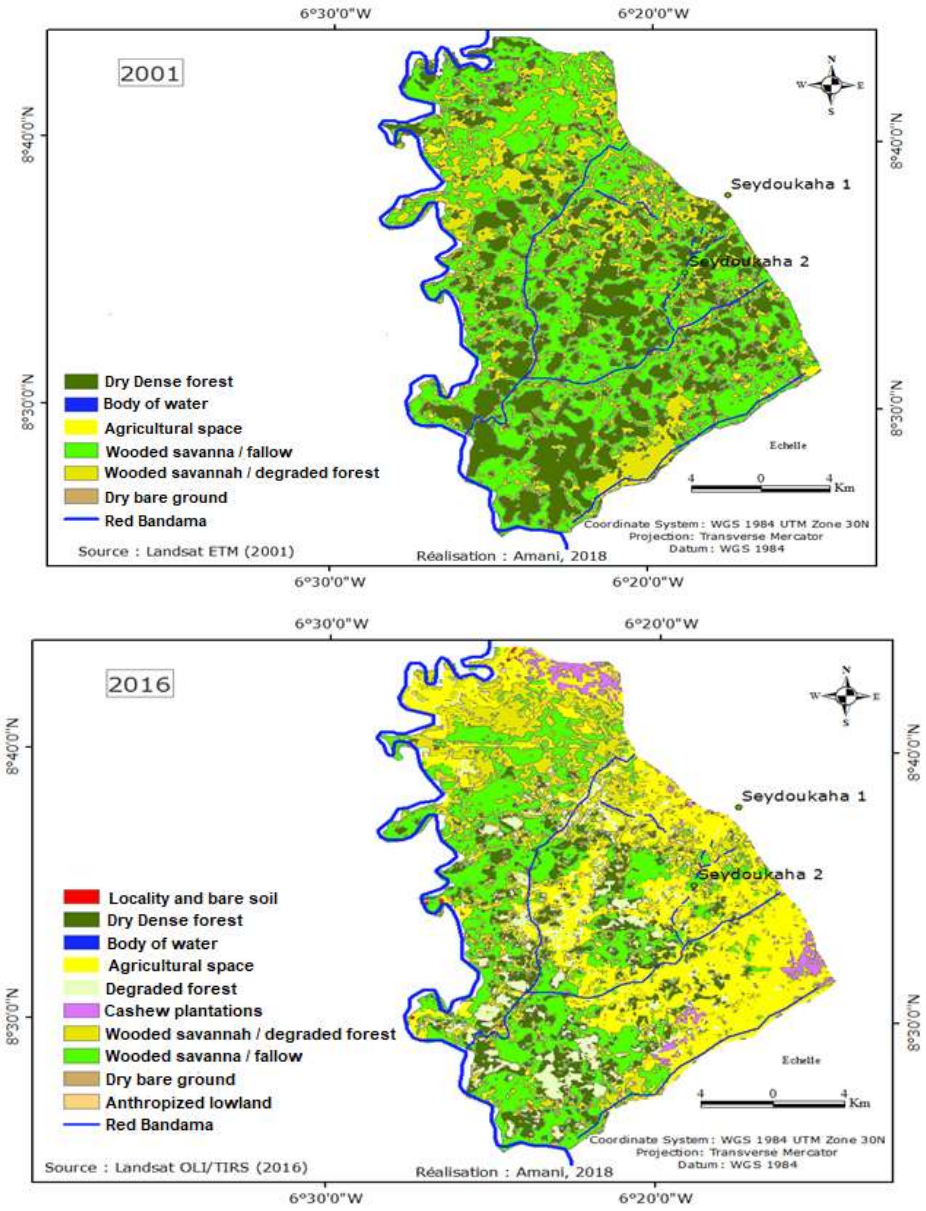


Figure 2: Land use of the red Kani Bandama classified forest (East) in 1986, 2001 and 2016 (Source: Landsat TM + (1986), Landsat ETM + (2001), Landsat OLI / TIRS (2016)

Table 1: Area and proportion of land use types in the classified forest of Kani Bandama rouge (East) in 1986, 2001 and 2016

	Area 1986		Area 2001		Area 2016	
Types of land cover	Ha	%	Ha	%	Ha	%
Dry Dense forest	14943	30,3	12911	26,2	4857	9,85
Body of water	113	0,2	93	0,2	121	0,23
Agricultural space	192	0,4	625	1,3	15179	30,82
Wooded savanna / fallow	25506	51,7	22551	45,8	13270	26,94
Wooded savannah / degraded forest	7870	16,0	12598	25,6	14237	28,91
Dry bare ground	674	1,4	516	1,0	27	0,04
Locality and bare soil	-	-	-	-	133	0,26
Cashew plantations	-	-	-	-	1255	2,54
Anthropized lowland	-	-	-	-	210	0,41
TOTAL	49298	100	49298	100	49298	100

The classified forest of Kani Bandama rouge: competition space between farmers and herders

The Red Kani Bandama Classified Forest is a picture of the saturation of space in Dianra Department. In fact, pastoralists are infiltrating there for lack of space for their activities in rural areas. For these pastoralists, the classified forest constitutes an important reservoir of resources for their activities because of the availability of water and fodder. However, pastoralists are not the only ones to occupy the classified forest. In addition to the breeders, we also note the installation of agricultural settlers inside the classified forest for the cultivation of various agricultural crops (cocoa plantation, cashew plantation, cotton cultivation and food crops (corn, cassava, banana, rice ... etc.) and which leads to the creation of camps (photo 1 and 2).

Photo 1: Cocoa plantation in the classified forest of Kani Bandama rouge (Photo AMANI R, 2016)

Photo 2: Seydoukaha 2 camp in the classified forest of Kani Bandama rouge (Photo: AMANI R**, 2016)**

The massive infiltration of pastoralists and farmers in the classified forest of Kani Bandama rouge in the department of Dianra started in the years 2002 following the military political crisis in Côte d'Ivoire. This crisis has weakened the legitimacy of the state. The classified forest which was an expended area has lost its protection and has become the object of envy on the part of farmers and herders.

According to the head of the forestry unit of the Forest Development Company (SODEFOR) of Kani-Bandama rouge, the classified forest of Bandama rouge, recorded in 2014, a human infiltration rate of more than 50%.

Within these classified forests, herders and farmers considered their presence legitimate. According to them, they were installed in this classified forest by natives claiming to be land owners of this state space.

For the breeders, their presence in the classified forest is legitimate insofar as the administrators of the classified forest guarantee their presence by means of an access ticket. From then on, they graze the herds on the entire perimeter of the classified forest without concession of land for development by farmers.

This double presence of farmers and breeders unequally settled in the classified forest of Kani Bandama rouge represents a window of major conflicts that arose in the department of Dianra with the result of several injuries and the destruction of herds (photos 3 and 4).

Photo 3: *Oxen slashed with machetes during a Conflict in the classified forest of Kani Bandama rouge (Photo: MIRAH de Dianra, 2016*)

Photo 4: Bouvier beaten by agricultural settlers from the classified forest of Kani Bandama rouge (Photo: MIRAH de Dianra, 2016)

DISCUSSION

Remote sensing and GIS have respectively made it possible to characterize the types of land use and analyze the changes made in the classified forest of Kani Bandama rouge. They are proving to be remarkable tools in the assessment and monitoring of spatial changes. Konan E. (2008) used these tools to understand the landscape dynamics in the Azagny National Park.

The maps produced and the various statistical calculations made it possible to measure the spatial evolution of the different types of land use in the classified forest of Kani Bandama rouge. The dynamics of the vegetation cover in particular is weak and relatively well preserved between 1986 and 2001. This remark is contrary to that of the studies carried out in the south of Côte d'Ivoire at the same period because of the cultivation of coffee and cocoa that have had a negative impact on forests. This is indicated by Konan D. (2009), in the region of Oumé), on the dynamics of agroforestry formations in Côte d'Ivoire.

From 2001 to 2016, the surface of the classified forest of Kani Bandama rouge was completely transformed into agricultural space with an increase in cashew orchards. The infiltration of the classified forest by farmers and herders creates tensions between the actors that are important because of the proximity of fields and pastures. Trianneau, (2012) poses the same problem of the lack of limit between spaces for agricultural use and space for pastoral use as a factor contributing to the occurrence of conflicts between farmers and herders.

CONCLUSION

The analysis of the evolution of the land use of the territorial space of the Dianra department was based on Landsat TM satellite images of (1986), ETM + of (2001) and OLI / TRIS of (2016). The cartographic results made it possible to understand the spatial forms and the dynamics of the different types of land use from 1986 to 2016. Indeed, the distribution of land use types is marked by a dominance of wooded / fallow savannah. And dense dry forests.

From 2001 to 2016, the area of the classified forest of Kani Bandama rouge (East) was completely transformed into agricultural area with an increase in cashew orchards.

The dynamics observed are linked to the gradual depletion of agricultural land and pastures around the forest which leads farmers and herders to infiltrate the forest. The cohabitation of farmers and herders in the classified forest often results in conflicts which have become frequent and have resulted in violent clashes resulting in material damage and loss of human and animal life.

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