Dynamic of the vegetation and climatic variables in Dimbokro Department, Central Côte d'Ivoire

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Abstract

The combined effects of both temperature increasing and human activities intensification in the tropics have a direct consequence as the perturbation on the natural vegetation cover. In order to better understand this process, the present study was undertaken in Dimbokro Department through a mapping and analysis of the spatial and temporal evolution of land cover types based on 29 years period (1988-2017) satellite images (Landsat 4 TM and Landsat 8 OLI/TIRS). A diachronic analysis of satellite data and a supervised classification using OLI 5/6/4 colorful compositions allowed a better discrimination of the land use types. The forests of plateaus, the riparian forests and the nude soils or localities decreased in area, while the shrubby savannas, the forests plantations and the fallows or crops lands increased in area. The overall accuracies for the classified images were 96.76% (1988) and 97.70% (2017), while the Kappa coefficients were estimated at 0.96 (1988) and 0.97 (2017). The riparian forests and the nude soils or localities were the land use types that have lost the most area with respective rates of change of -30.36% and -47.45%.

Key words: West Africa, satellite images, temperature, spatio-temporal evolution, land uses.

Résumé

The combined effects of both temperature increasing and human activities intensification in the tropics have a direct consequence as the perturbation on the natural vegetation cover. In order to better understand this process, the present study was undertaken in Dimbokro Department through a mapping and analysis of the spatial and temporal evolution of land cover types based on 29 years period (1988-2017) satellite images (Landsat 4 TM and Landsat 8 OLI/TIRS). A diachronic analysis of satellite data and a supervised classification using OLI 5/6/4 colorful compositions allowed a better discrimination of the land use types. The forests of plateaus, the riparian forests and the nude soils or localities decreased in area, while the shrubby savannas, the forests plantations and the fallows or crops lands increased in area. The overall accuracies for the classified images were 96.76% (1988) and 97.70% (2017), while the Kappa coefficients were estimated at 0.96 (1988) and 0.97 (2017). The riparian forests and the nude soils or localities were the land use types that have lost the most area with respective rates of change of -30.36% and -47.45%.

Key words: West Africa, satellite images, temperature, spatio-temporal evolution, land uses.

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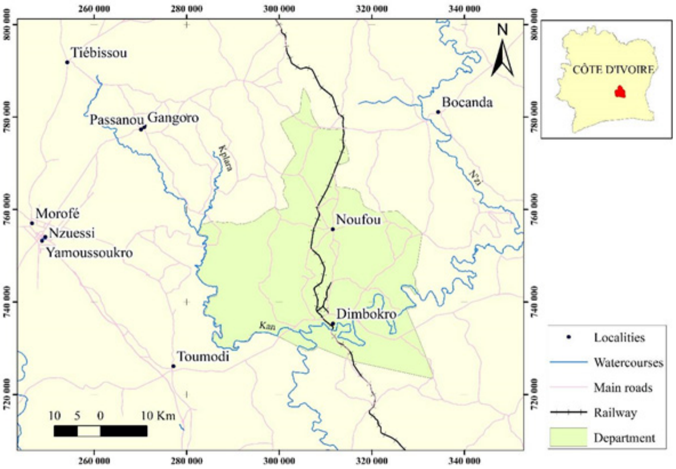
1. INTRODUCTION

Archaeological researches showed that prehistoric man already exploited his environment (Eggert 1993). But during the recent decades, the natural vegetation is disappearing very quickly (Spichiger et al. 2000) under a high human pressure in the Tropics (Bamba et al. 2008; Ouédraogo et al. 2009). Various human activities including agriculture and forest logging that involve heavy machineries and chemical products, hunting, water flows, bush fire, vegetation clearance for cities and non-timber forest products (Kouamé 2016) led to a deep modification of the natural environment. Consecutively there is the current decreasing of natural vegetation area (Kouamé and Zoro Bi 2010) and impoverishment of the original flora and the soil fertility (Guillaumet et al. 1971). Unfortunately, in most tropical countries, and especially in Africa, the derived savannas occupy very large areas nowadays. Some authors including Spichiger et al. (2000) attribute the replacement of tropical rainforest by the derived savannas to climate change. These two phenomena seem to be interconnected since massive deforestation in the Tropics also affects the regional climate (Parmentier et al. 2007). The natural distribution of vegetation main types in the Tropical Africa follows both geographical coordinates and climatic factors (Parmentier et al. 2007, 2011). This study aims to assess the remaining forest cover in the Department of Dimbokro in order to ensure better protection However, the different types of biotopes found in the Department of Dimbokro are undergoing a modification of the vegetation cover in time and space as a result of anthropic pressures. This manuscript describes the evolution of the land use types between 1988 and 2017 as a response to the local temperature increasing and the human pressure in Dimbokro which is one of the hottest areas of Côte d'Ivoire (Brou et al. 2005). The objective of this study is to characterize the spatio-temporal dynamics of land use types in Dimbokro from 1988 to 2017, given that temperature increasing in this forest-savanna contact zone can strongly alter the dynamics of forests and other ecosystems in many ways (Mortsch 2006). We therefore hypothesised that land use types would show different responses to human activities and temperature variation in Dimbokro Department.

2. Materials and methods

2.1. Study zone

The Department of Dimbokro is located in the centre-eastern part of Côte d'Ivoire (Figure 1). Dimbokro town is the main city of the N'Zi Administrative Region which is bordered in the North by Bocanda area, in the South by Tiémélékro area, in the East by Bongouanou area and in the West by Toumodi and Yamoussoukro areas (Figure 1). Its geographical area extends between 6°37' and 6°47' North latitude and between 4°38' and 4°45' West longitude and covers an area of 161.9 km² (Figure 1).



Weiss M., Jacob F. and Duveiller G., (2020). Remote sensing for agricultural applications: A meta-review. *Remote Sensing of Environment,* 236, 111-122.
Zhu X.X., Tuia D., Mou L., Xia G.-S., Zhang L., Xu F. and Fraundorfer F., (2017). Deep learning in remote sensing: A comprehensive review and list of resources. *IEEE Geoscience and Remote Sensing Magazine,* 5(4), 8-36.

Figure 1. Location and presentation of the Dimbokro Department.

The relief is not very rugged and shows an overall monotony with low hills (Avenard 1971). The soils are mostly ferralitic (Perraud 1971). The hydrographic network is composed of the N'Zi, Agnéby, Comoé rivers and their tributaries (Guillaumet et al. 1971). Annual minimum and maximum temperatures changed respectively from 23 and 32.5 in 1979 to 23.2 and 34.8 in 2019. The monthly temperatures over these 40 last years showed 20.4-23.3 °C minimal temperature, 29.9-35.4 °C maximum temperature and 25.9-29 °C mean temperature (Table I). The monthly rainfall for the same period varied from 11 to 200 mm (Table I), while the sunshine mean duration was set between 3 and 7 hours per day.

Table I. Monthly temperatures and rainfall in Dimbokro Department from 1982 to 2012. Source : fr.climate-data.org/afrique/cote-d-ivoire/lacs/dimbokro-58625

Climatic factors/Months	January	February	March	April	May	June	July	August	September	October	November	December
Mean temperature (°C)	27	29	29	28.8	28.3	27	26.1	25.9	26.5	27	27.5	26.5
Minimal temperature (°C)	20.4	22.7	23.2	23.3	23.1	22.5	22	21.9	22.1	22.3	22.3	21
Maximal temperature (°C)	33.7	35.4	34.9	34.4	33.5	31.6	30.2	29.9	30.9	31.8	32.7	32.1
Precipitations (mm)	11	50	111	130	150	188	104	71	132	116	52	20

2.2. Methods for mapping the current land cover

The mapping process included three main successive phases which consisted of the classification of satellite images, the validation of this classification and the characterization of land cover dynamics.

Two Landsat satellite images (TM of 24 December 1988 and OLI/TIR of 14 January 2017) covering scene 196/055 were downloaded from the http:earthexplorer.usgs.gov website. All the images were taken during the dry season to avoid the clouds and a comparison of images from different seasons which could lead to non-comparable results (Noyola-Medrano et al. 2008; Kpedenou et al. 2016). The WGS 84 system with the UTM 30 North projection for georeferencing the images were used. The mapping methodology was based on the processing of Landsat data (2017 and eventually 1988) and was supplemented by the ad hoc acquisition of data from other satellites (SPOT, IKONOS, Quickbird, etc.) from recent archives when Landsat data were unavailable or of poor quality. The shape files of the administrative boundaries, hydrographic network as well as communication roads were downloaded online from https://www.openstreetmap.org website.

Four field trips using a GPS were necessary to validate the classification. The vegetation cover changes during these 29 years were raised up following the requirement of 10 years minimum to better perceive changes in the vegetation (Lambert 2012).

2.3. Digital image processing by calculating spectral indices

The process of images digital classification involved the choice of the colorful compositions and of the classification algorithm. The unsupervised classification was maintained when it corresponded to the field observations. After the classification validation, a 3x3 median filter reduced the intra-class heterogeneity by deleting isolated pixels. The variations of land cover types along time were analysed using ArcGIS 9.2 and Envi 5 software following Schlaepfer (2002). The Kappa coefficient which establishes a relationship between a map and the ground reality was calculated and a confusion matrix showing the error levels in the allocation of pixels between the different classes (Godard 2005) was analysed.

2.3.1. Detection of change by the Ground Surface Temperature

The Ground Surface Temperature (GST) was calculated to detect the rates of change at the ground surface between 1988 and 2017. This temperature was obtained by Planck's law conversion of luminance in the thermal infrared, which was then corrected for emissivity effects using the Temperature Independent Spectral Indices of Emissivity (TISIE) model (Li and Becker 1993; Wan and Li 1997). GTS is regulated by vegetation and is determined from the relationship between the gloss temperature and the surface emissivity (Williams and Smith 1990; Prata et al. 1995).

$$\mathbf{GTS = TB/ (1 + (\lambda\ TB/ \rho) \ln\varepsilon} \qquad \text{Equation (1)}$$

$$\mathbf{TB = K_2 / (\ln(K_1/ L\lambda + 1))} \qquad \text{Equation (2)}$$

with :

$$\mathbf{\rho = h \times c / \sigma\ (1.438 \times 10\text{-}2\ m\ K)} \qquad \text{Equation (3)}$$

Where GTS: ground surface temperature (in Kelvin converted into degree Celsius), TB: gloss temperature (in Kelvin); K1 and K2: constants applied for Landsat OLI/TIRS, Lλ: spectral radiance at sensor aperture, λ: wavelength of emitted radiation (11.5 µm), σ: Stefan Boltzmann constant (1.38 × 10-23J K-1), h: Planck constant (6.26 × 10-34 J s), c: speed of light (2.998 × 108 m / s), and ε: emissivity.

GTS is the using the fraction of Plant Cover (CV) described by Valor and Caselles (1996) and calculated as follows:

$$\mathbf{CV = (NDVI - NDVImin)^2 / (NDVImax - NDVImin)^2} \qquad \text{Equation (4)}$$

where NDVI was Normalized Difference Vegetation Index

2.3.2. Detection of change by the NDVI

The rate of change in vegetation cover was calculated using the NDVI, which characterizes the leaf biomass of the vegetation cover over time (Vancutsem et al. 2006) between the Near Infrared and the Red canals. Denis (2013) set the NDVI values for satellite images at close to 0 for open water surface, at 0.1-0.2 for nude soil and at 0.5-0.8 for dense vegetation. The NDVI is directly related to the photosynthetic activity of plants and therefore to the energy absorption capacity of the canopy; it becomes an indicator of plants chlorophyll biomass (Denis 2013) calculated through the following formula:

$$\mathbf{NDVI = (PIR\text{-}Red) / (PIR+Red)} \qquad \text{Equation (5)}$$

where PIR: near-infrared canal et R: red canal.

2.3.3. Detecting change by Normalized Difference floor gloss Index

As the previous indices, the Normalized Difference floor gloss Index (NDBI) of Crist and Cicone (1984) was calculated to detect changes in the area covered by the floor between 1988 and 2017. This index uses the infrared (PIR) and mid-infrared (MIR) canals to highlight the settlements.

$$\mathbf{NDBI = (MIR-PIR) / (MIR+PIR)} \qquad \text{Equation (6)}$$

The positive values (light colors) of this index correspond to the presence of nude soils, and the negative values (dark colors) indicate a vegetation.

2.3.4. Colorful compositions

The colorful compositions was achieved by combining information from three spectral bands of a satellite sensor and displaying it simultaneously in the three primary colors (red, green and blue). These colorful compositions was created in order to obtain a good visualization of the different types of plant formations. Thus, the creation of colorful compositions was exported into a Geographic Information System database type for the preparation of field sites to be visited and for the characterization of land use types.

2.3.5. Validation of the classification

The validation of the satellite images consisted into the comparison of the image classes resulting from the different spectral signatures of the satellite images to the field data. The different land use types in the study area were georeferenced during a week field trip through 43 local points. These georeferenced local points were digitized with ArcGIS 9.2 software to be compared to the classes from the Landsat images preprocessing as well like in numerous remote sensing studies (Zhu et al. 2017, Ma et al. 2019, Wang and Gamon 2019, Cheng et al. 2020, Weiss et al. 2020). A supervised classification was carried out by comparing the training points from the image to the control points from the field. The produced map is accompanied by a Kappa coefficient and a confusion matrix. The Kappa coefficient establishes a relationship between the produced map and the field reality. The higher coefficient means the map is much closed to the truth on the field (De Raadt et al. 2019, Foody 2020). The confusion matrix shows the levels of error in the allocation of pixels between the different classes (Godard 2005, Ruuska et al. 2018).

2.3.6. Spatial and temporal analysis of the land use types

The combination of spatial and temporal components in remote sensing consisted in determining the rate of land cover change calculated between 1988 and 2017, and generating the change map for the evolution of land cover types. In order to facilitate and synthesize the analysis of the global evolution of land use, seven land use units as riparian forests, forests of plateau, plantations forest, woody savannas, shrubby savannas, fallow or crops lands and nude soils or localities were monitored from 1988 and 2017 photos. A transition matrix between 1988 and 2017 let to detect the slightest changes as an increase, a decrease or a stability in the land use types. A positive change in land cover corresponds to a gain in land cover, while the negative change corresponds to a loss of coverage. Thus, to find the rate of change in temperature, chlorophyll activity, water surfaces and vegetation cover, a subtraction was made between progression and regression for each index. Finally, the rate of change (Tc) in land cover was calculated between 1988 and 2017 as described by Toyi et al. (2013) using the following formula:

$$Tc = (A2 - A1/A1) \times 100 \quad \text{Equation (7)}$$

where A1 and A2 were the initial and final area of the land use type, respectively.

3. RESULTS

3.1. types of land use in dimbokro county

3.1.1. ground surface temperature

the dark red coloration on the gst image corresponding to the higher temperature surface moved from the south-western part of the study area (figure 2 zone a) in 1988 to the north-western (figure 2 zone c) in 2017. the orange-yellowish coloration expressing lower temperature moved from the south-eastern of the dimbokro department (figure 2 zone d) in 1988 to the northern (figure 2 zone c) in 2017.

the evolution of the temperature in dimbokro department between 1988 and 2017 (figures 3 & 4) showed a rise in temperature in both the south-western and northern zones. the eastern-north and western zones showed a drop in temperature, while the centre of dimbokro department expressed mainly a stable temperature between 1988 and 2017 (figures 3 & 4).

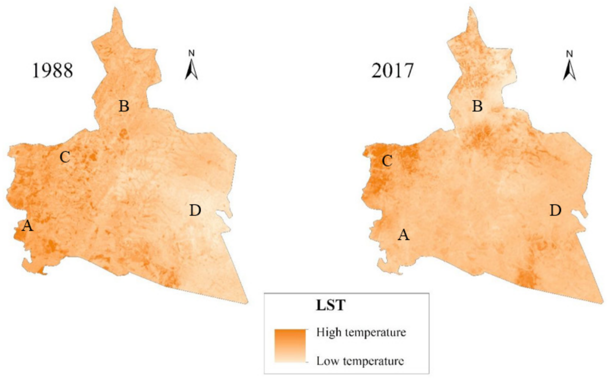


Figure 2. Evolution of the ground surface temperature between 1988 and 2017 in Dimbokro Department

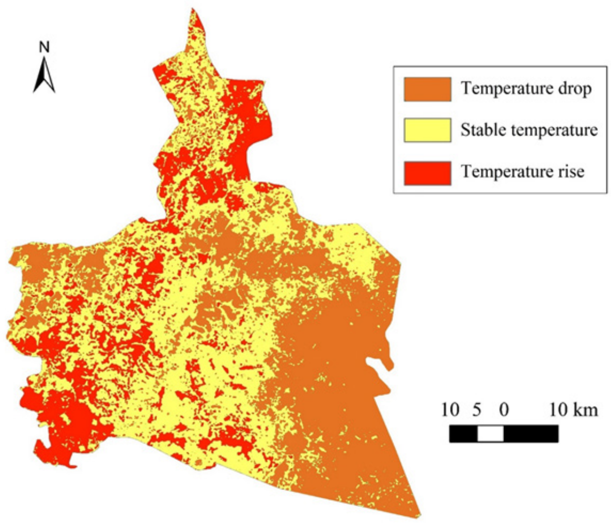


Figure 3. Evolution of the ground surface temperature between 1988 and 2017 in Dimbokro Department

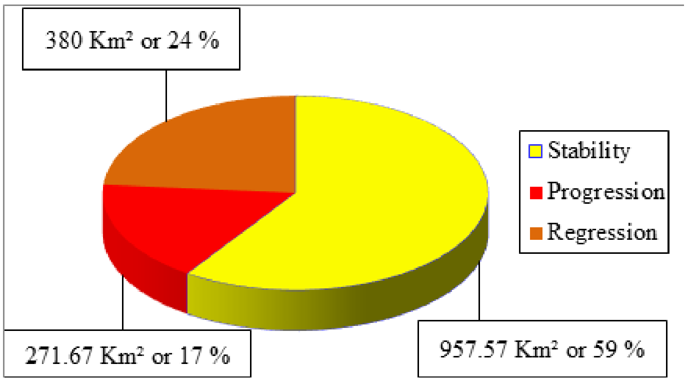


Figure 4. Temperature evolution between 1988 and 2017 in Dimbokro Department

3.1.2. Vegetation index by normalized difference or Tucker index

The highest chlorophyll activity in 1988 was recorded in the Eastern zone (Figure 5 zone D), while the lowest chlorophyll activity was reported in Western zone (Figure 5 zone A). In 2017, the Eastern zone showed the highest chlorophyll activity (Figure 5 zone D), while the lowest chlorophyll activity was extended from the Western to the Central and Northern zones (Figure 5 zones A, B, C). In terms of the chlorophyll level evolution from 1988 to 2017 in Dimbokro Department, the overall tendency was a stability on 82 % of the Department (Figures 6 & 7). The 8% change was a decrease of the chlorophyll level on 85.11 km² mainly in the Western zone and an increase on 214.41 km² mainly in both Eastern-north and Eastern-south zones (Figures 6 & 7).

3.1.3. Normalized Difference Soil Brilliance Index

The evolution of the NDBI from 1988 to 2017 showed the highest values in the Eastern zone, while the lowest values were found in the Western zone (Figures 8 & 9). But there was a slight decrease of the NDBI in the Northern, Central and Eastern zones during that period. In terms of the NDBI change spectrum between 1988 and 2017, the Department experienced 37.73% of change, which was a loss of 613.92 km² and an extension of 6.38 km² (Figures 8 & 9).

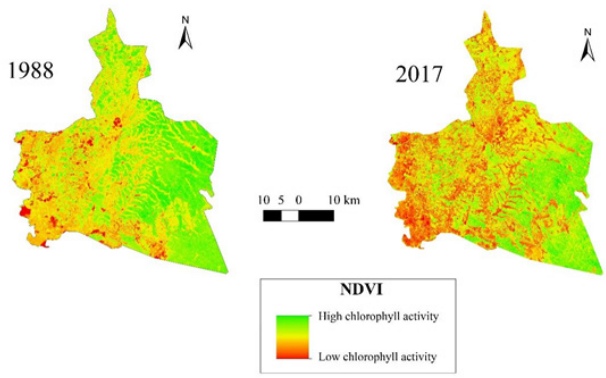


Figure 5. Evolution of the chlorophyll activity between 1988 and 2017 in Dimbokro Department

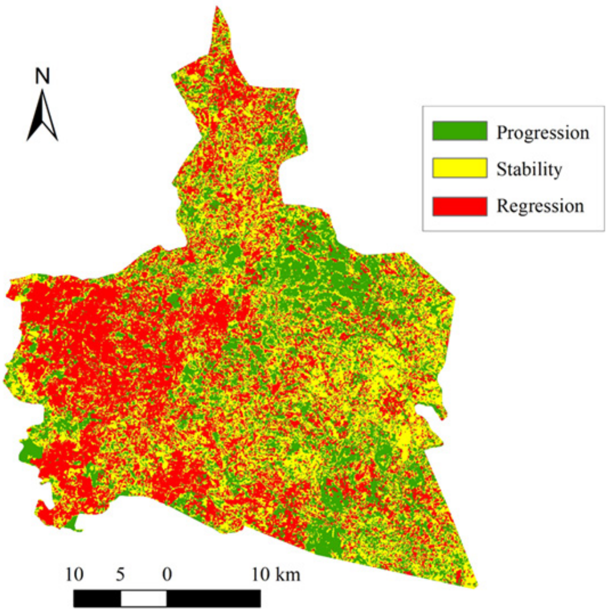


Figure 6. Evolution of the chlorophyll levels between 1988 and 2017 in Dimbokro Department

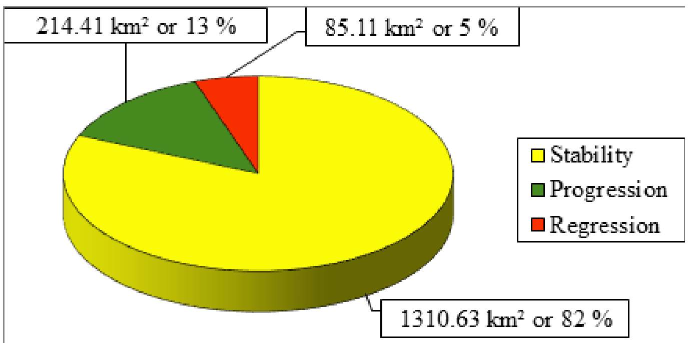


Figure 7. Evolution of chlorophyll activity between 1988 and 2017 in Dimbokro Department

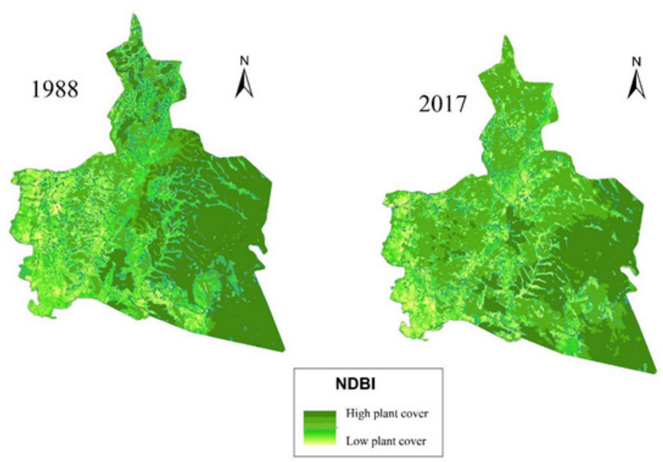


Figure 8. Evolution of the plant cover levels in 1988 and 2017 in Dimbokro Department

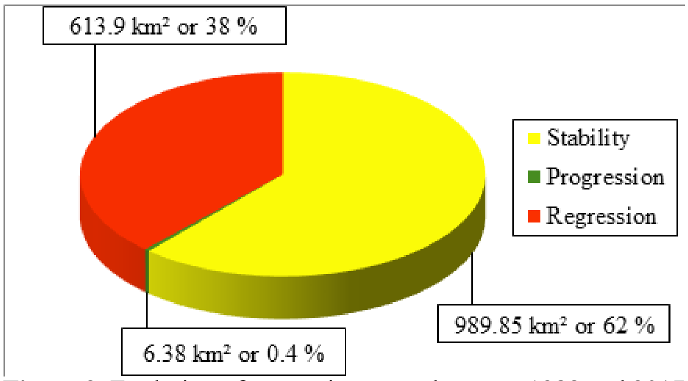


Figure 9. Evolution of vegetation cover between 1988 and 2017 in Dimbokro Department.

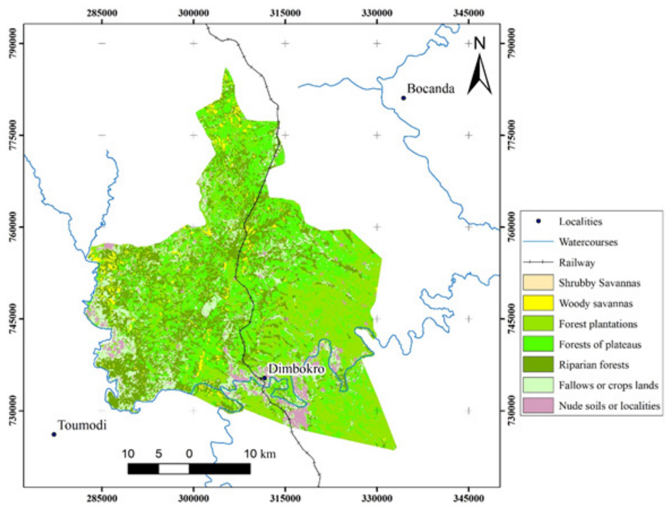


Figure 10. Compositions of the 2017 landsat image showing the oli 5/6/4

3.2. Validation of classification results

The different colorful compositions OLI5, OLI6 and OLI4 of 2017 Landsat images discriminated as well the land use types (Figure 10) the major colorations which were the clear green and dark green. The different classifications were evaluated by the confusion matrices and the Kappa coefficient (Tables II & III). These matrices showed overall map accuracies of 96.76% for 1988 Landsat TM image and 97.70% for 2017 Landsat OLI-TIRS image. The Kappa coefficients were set at 0.96 for 1988 image and at 0.97 for 2017 image (Tables II & III). A closer analysis showed that a minor confusion was observed between some land use types. In 1988, the highest confusion is found between the woody savannas and the shrubby savannas, and between the nude soils or localities and the woody savannas (Table II). These confusions were 3.73% and 3.66% respectively. In 2017, the highest confusion was between the fallows or crops land and the nude soils or localities, with a value of 5.42% (Table III).

3.3. Evolution of the land use types

The land use map of the different vegetation formations in Dimbokro County between 1988 and 2017 (Figure 11) showed a total of seven land use classes. These are fallows or crops lands, reparian forests, forests of plateaus, forest plantations, savannas (shrubby and woody) and nude soils or localities. The latter (nude soils) reached the Southern zone of Dimbokro Department (Figure 11).

Table II. Confusion matrix for the classification of the 1988 image**.** Total accuracy = (18501/19121) 96.76%, Kappa coefficient = 0.96. The values in bold diagonal correspond for each class to the well-ranked pixel rates. The various off-diagonal rates reflect the rates of poorly ranked pixels that have been assigned to a class to which they do not belong.

Classes	Woody savannas	Fallows or crops lands	Forest plantations	Forests of plateaus	Riparian forests	Shrubby Savannas	Nude soils or localities
Woody savannas	95.87	0	0	0	0	0	0
Fallows or crops lands	3.73	93.81	0	0	0	0	0
Forest plantations	0.03	0.67	96.37	0.53	0	0	0
Forests of plateaus	0.09	0	1.16	98.18	1.46	0.09	0.93
Riparian forests	0.28	1.87	2.22	0.4	98.1	1.15	0.28
Shrubby Savannas	0	3.66	0.25	0.73	0.44	98.38	1.87
Nude soils or localities	0	0	0	0.17	0	0.38	96.92
Total	100	100	100	100	100	100	100

Table III. Confusion matrix for the classification of the 2017 image. Total accuracy = (11842/12121) 97.70 %. Kappa coefficient = 0.97. The values in bold diagonal correspond for each class to the well-ranked pixel rates. The various off-diagonal rates reflect the rates of poorly ranked pixels that have been assigned to a class to which they do not belong.

Classes	Woody savannas	Fallows or crops lands	Forest plantations	Forest of Plateaus	Riparian forests	Shrubby Savannas	Nude soils or localities
Woody savannas	99.09	0.00	0.00	0.00	0.00	0.00	0.00
Fallows or crops lands	0.04	94.30	0.00	0.33	0.00	0.00	0.00
Forest plantations	0.61	0.00	98.58	1.99	0.00	0.00	0.00
Forests of Plateaus	0.00	1.38	0.41	95.35	0.00	0.00	1.10
Riparian forests	0.00	4.32	0.28	0.00	97.25	0.87	0.15
Shrubby Savannas	0.23	0.00	0.73	2.33	2.75	93.71	1.32
Nude soils or localities	0.04	0.00	0.00	0.00	0.00	5.42	97.44
Total	100	100	100	100	100	100	100

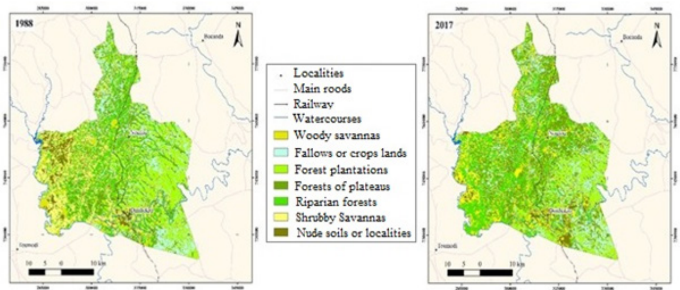


Figure 11. Evolution of land use types in Dimbokro Department in 1988 and 2017

In terms of change rate of land use types, the overall Dimbokro Department experienced a rate of 6.79% corresponding to an increasing area of 17% (271.67 Km²) of the savannas (shrubby and woody), the fallows or crops lands, the forests of plateaus and forest plantations, and a decreasing area of 23.66% (380.90 Km²) of the nude soils or localities and the riparian forests (Figures 12 & 13, Table IV). The riparian forests lost 30.36% of its area, while the nude soils or localities experienced a regression about 47.45% of its (Figures 11 & 12, Table IV) from 1988 to 2017. The shrubby savannas, the forest of plateaus and the fallows or crops lands showed a slight increase in area, while the woody savannas and the forest plantations got the higher positive rates of change with 93.40% and 205.05% of their respective areas (Figures 11 & 12, Table IV).

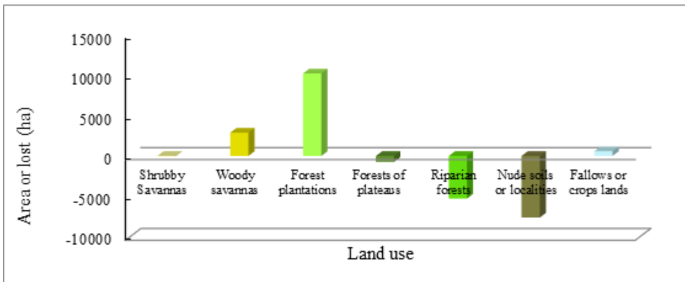


Figure 12. Changes in Dimbokro Department land use types between 1988 and 2017.

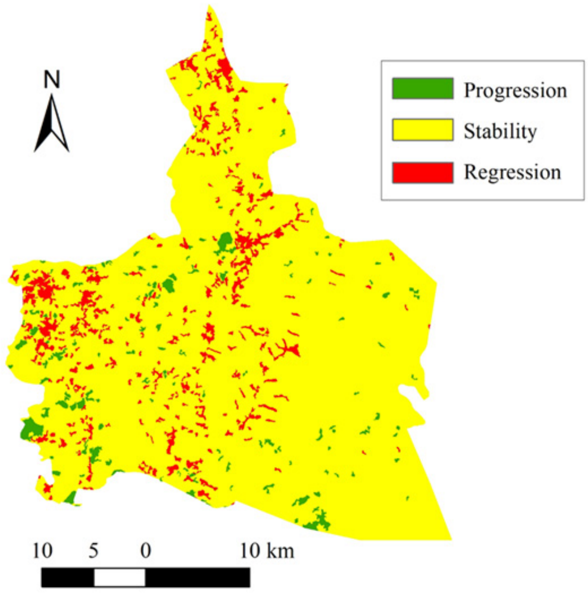


Figure 13. Changes in land use types between 1988 and 2017 in Dimbokro Department

Table IV. Matrix of the land use types change in Dimbokro Department from 1988 to 2017.

	Year 1988							
Surface (ha)	Woody savannas	Fallows or crop lands	Forest plantation	Forest of plateaus	Riparian forests	Shrubby Savannas	Nude soils or localities	Total
Year 2017: Woody savannas	94.31	1.1	0.14	0.03	0.05	0.01	0.01	100
Fallows or crop lands	0.87	15.57	5.11	2.51	12.56	14.76	8.42	100
Forest plantation	0.71	4.65	52.33	48.7	15.91	3.23	2.81	100
Forest of plateaus	0.97	13.09	29.77	37.2	38.2	14.01	7.82	100
Riparian forests	1.16	35.1	4.12	2.71	21.77	36.84	24.4	100
Shrubby Savannas	1.34	20.34	6.17	7.43	9.88	22.51	32.1	100
Nude soils or localities	0.65	10.15	2.38	1.45	1.64	8.65	24.4	100
Total Land uses	100	100	100	100	100	100	100	-

The change matrix of the cross-referencing of 1988 and 2017 land use maps of Dimbokro Department showed a change in the different land use types areas which was a decrease of 5.69% (367 325 ha) vegetation and an increase of 5.52% (355 984 ha) vegetation (Table V).

Table V. Overall land use types change in Dimbokro Department from 1988 to 2017.

Nature of change	Area (ha)	Importance (%)
Stability	5 729 291	88.79
Progression	355 984	5.52
Regression	367 325	5.69
Total	6 452 600	100

3.6. Relation between climatic variables and the land use types

In 1988, the Eastern zone of Dimbokro Department occupied mainly by the forest plantations, the fallows or crops lands and the riparian forests (Figure **7**) showed the highest chlorophyll activity level (Figure 4), the lowest ground surface temperature (Figure 2) and the highest value of NDBI (Figures 8 & 9). The Western zone of Department was covered mainly by the savannas (shrubby and woody), the nude soils or localities and the forests of plateaus (Figure **7**) and experienced the lowest chlorophyll activity level (Figure 4), the lowest land surface temperature (Figure 2) and the lowest value of NDBI (Figures 8 & 9).

4. DISCUSSION

The overall high map accuracies about 96.76% for 1988 Landsat TM image and 97.70% for 2017 Landsat OLI-TIRS image, and the Kappa coefficients of 0.96 for 1988 image and at 0.97 for 2017 image showed that the classification of the land use dynamics in Dimbokro Department (Figure 10) was very correct as well as recommended Pontius (2000), De Raadt et al. (2019) and Foody (2020). Thus, these maps (Figures 10, 11 & 13) experienced the field truth and the slight confusions found between the riparian forests and woody savannas, on the one hand, and between the fallows or crops lands and the nude soils or localities, on the other hand (Tables II & III), could be due to the physiognomy of these vegetation, which should be favourable to very close spectral responses. Therefore, the classification of the land uses into seven types (Figures 10-12, Tables II-IV) was very good and allowed to evaluate the land use change over the 29 years dynamics (Figures 11-13, Table IV). Many authors in Côte d'Ivoire, specially N'Guessan et al. (2003), Goetze et al. (2006), Barima (2009), Barima et al. (2009, 2010) and Sangne et al. (2015) stressed that the use of remote sensing indices provide useful and potential information for the knowledge of the state of the vegetation cover of an area. Elsewhere, others authors like Wang and Gamon (2019) and Weiss et al. (2020) gave the same conclusion.

The relationship of the GST (Figures 2 & 3) with the chlorophyll activity and level (Figures 5 & 6), and with the plant cover level (Figure 8) was conform to Benkahla (2011) who found the lower surface temperature in the higher vegetation density area and certified that the vegetation regulates the surface temperature by absorbing the radiant energy and re-emitting it as latent heat through the process of evapotranspiration. The areas of Dimbokro Department with the highest land use change from 1988 to 2017 was the forest plantations (Figures 8, 11 & 12) that increased and corresponded to the area of the highest chlorophyll level (Figure 5). These forests plantations belonging to the Société de Développement des Forêts domain were largely monospecific plantations made up of species such as Gmelina arborea Roxb., Senna siamea (Lam.) Irw. & Barn. and Tectona grandis L.f. and where the canopy was very closed by large trees (Kouamé 2017).

Meneses-Tovar (2011) stated that NDVI was an indicator of forest health, while Tra Bi (2013) underlined the correlation between the chlorophyll activities and the anthropogenic activities. In Dimbokro Department, the establishment of the crops like yam, cassava, palm oil, rice, cashew and banana was the main cause of the regression of both the riparian forests and the nude soils or localities (Figure 12) as have shown Kissinger et al. (2012) and Tchatchou et al. (2015). Ningal et al. (2008) showed that the evolution of agricultural areas to the detriment of vegetation cover was a threat of the forest areas. Mama and Oloukoi (2003), Kissinger et al. (2012) and Tchatchou et al. (2015) distinguished the direct and indirect causes of the vegetation cover degradation. The direct causes were related to human activities including charcoal production, the medicinal plants extraction, logging, bush fires, forest clearance etc. by the rural populations. The Indirect causes were related to the poverty of the local populations, which harvest the vegetation for the financial means or to their primary needs such as the health, the meat, the food etc.

5. CONCLUSION

The analyses of Landsat TM satellite images from 1988 and OLI/TIRS satellite images from 2017 showed the spatial and temporal dynamics of the landscape and land use types in Dimbokro Department. The unsupervised classification method discriminated land use types on the basis of remote sensing indices including GST, NDVI, NDBI and NDWI. These indices provided information on the heat exchange, the chlorophyll level and activity, the vegetation cover and dynamic. From 1988 to 2017, all the land use types increased in area more or less significantly except the riparian forests and the nude soils or localities, which decreased in area significantly in Dimbokro Department. A relationship was found between the land use types and the chlorophyll activity level and activity, and the GST, and the NDBI. Our hypothesis to find different responses of the land use types to human activities and temperature variation in Dimbokro Department was confirmed.

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CONFLICT OF INTEREST STATEMENT

The authors of this manuscript declare that they have no conflict of interest.

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