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Rainfall variability and anthropogenic activities influencing land use dynamics in Korhogo (Northern Côte d'Ivoire)

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ABSTRACT
This study aims to analyze rainfall variability and the anthropogenic disturbances impacts on spatial and temporal dynamics of land use in the sub-prefecture of Korhogo. Rainfall indices was analysed from 1983 to 2014. The land use change was studies using Landsat images of 1986 (TM), 2000 (ETM+) and 2015 (OLI). Rainfall variability analysis shows a general decrease of rainfall. The images processing shows as overall accuracy 84.63% in 1986, 87% in 2000 and 98% in 2015. Thematic maps highlighted spatial and temporal dynamics of vegetation cover. A progressive increase of the town of Korhogo between 1986 and 2015 with a strong degradation of the vegetation between 1986 and 2000, followed by a reappearance of the vegetation. This degradation was not simply due to climate change. Increasing anthropogenic pressure caused increased exploitation of ground, preventing the regeneration of vegetation at certain places and an extension of cropped areas.

KEYWORDS: *Côte d'Ivoire, Korhogo, land use, rainfall variability, remote sensing*

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I. INTRODUCTION

The studies relating to the variability and climate change interested the world community due to several important climate conditions such as the drought which especially touched West Africa since the seventies and also the recent phenomenon of El Niño [1, 2]. Côte d'Ivoire knew climate change impacts expressed by rainfall decrease and the rise of temperatures [3]. Over several years of remark**,** inter-annual rainfall fluctuates with often a succession of years sometimes in deficit sometimes surplus. But the general trend is down in Northern Côte d'Ivoire [4]. But the intensification of human activities due to the rapid population growth of this space can be favorable to the dynamics of land use and the modification of its environment. Land use dynamics in general and vegetable cover in particular, are related to the conjugation of the impacts of climate change and the upheavals related to the human activities [5]. Land use is a fundamental variable for regional planning like for environment comprehension and study [6]. In Korhogo, the use of the soil plays a significant role in the means of subsistence of the peasants and contributes to the socio-economic development of the area. But the rapid population growth and population need in various agricultural produce for food and energy led to a great pressure on this soil. Population increased from 453.006 in 1998 to 536 851 in 2014 with an annual average rate of 3.18% according to the National Institut of Statistics (INS). Moreover, Korhogo remains largely dependent on climate conditions and more particularly of rainfall variability. The inter-annual rainfall decreased from 1400 mm during 1950-1959 to 1200 mm between 1990 and 1999 [7]. One observes the introduction of a drier barren climate on the whole of the area, as well as a trend to the overall reduction in the useful rainfall [8]. The objective of the work is to analyze the influence of the changes in rainfall and the anthropogenic pressures on the spatial and temporal dynamics of land use in the sub-prefecture of Korhogo. Rainfall variations are analyzed from Nicholson index. To be able to propose a durable management of land use in this geographical space an evaluation of their state appears necessary, which can be done by using Remote Sensing. The dynamics of land use was carried out from a diachronic analysis of satellite images. Timely and up-to-date land cover information is required to formulate and implement effective sustainable development policies in the study area. However, such land cover information is sparse or lacking given the high cost of conducting conventional land cover surveys [9]. Medium resolution satellite remote sensing data are relatively inexpensive sources for mapping land cover at a regional scale [10]. More recently, there has been an increased use of medium resolution satellite data, such as Landsat Thematic Mapper (TM), Enhanced Landsat Thematic Mapper (ETM+) and Operational Land Imagery (OLI) imagery, since the datasets are available for free [11]. Although Landsat data have improved land cover mapping in tropical areas [12, 9], land cover mapping remains a challenge in these environmental ecosystem [10]. This is mainly attributed to a number of environmental and anthropogenic factors.

II. STUDY AREA

The sub-prefecture of Korhogo lie between 5°29'10" and 5°52'30" N longitudes and 9°21'40" and 9°45'W latitudes (fig. 1), some 600 km north of Abidjan. The study area covers an area of approximately 1449.5 km^2. The altitude varies from 250 m to 600 m above sea level. Climate is characterized by two principal seasons: The rainy season, which extends from May to October with a maximum rainfall in August. Annual rainfall has decreased significantly. The mean annual rainfall ranging from 1000 mm to 1200 mm. The strongest temperatures are recorded in this area. The low temperatures are observed from June to September and in January because of the harmattan. Daily average temperatures are approximately 29°C in dry season and 25°C in rainy season with an annual average maximum temperature in the range of 25°C-35°C. The area is essentially crossed by a tree savanna with an herbaceous trend. There could see in some place woodland, sacred woodland around the villages, as well as gallery forest along the rivers. The most dominant forest species is the cheese monger. One also finds the Néré and the Shea tree whose fruits are consumed and marketed by the populations. Due to agricultural activities and deforestation the natural vegetable covers are gradually replaced by orchards (mango, cashew nut, etc.) and by forest species retimbered (teak mainly) around the towns and villages. Three types of soils are observed. The area is covered with tropical ferruginous soil and ferralitic soil. One associates in some places the hydromorphic soil. In the countryside, the population is mainly agricultural. The soils are developed by the natives, especially for the perennial cultures. The economy of this area is essentially based on agriculture and the breeding. The principal practiced cultures are: the mango, cashew for the perennial cultures; cotton for the annual cultures; rice, corn, millet, sorghum for the food.

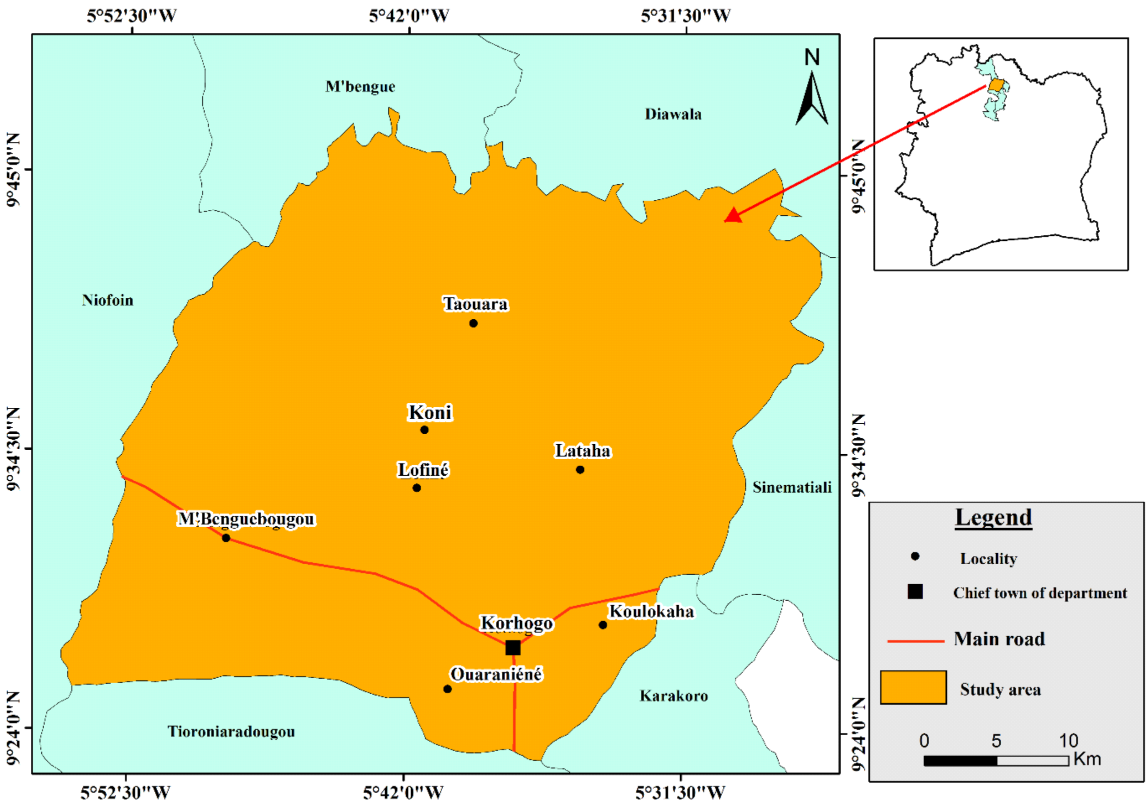

Fig. 1: Study area

III. MATERIAL AND METHODS

3.1 DATA

The climatic data used are monthly rainfall statements provided from SODEXAM (Société de Développement et d'Exploitation Aéronautique, Aéroportuaire et Météorologique). These data relate to Korhogo weather stations from 1983 to 2014. Landsat TM (1986), ETM+ (2000) and OLI (2015) were used to classify land use in the study area (Table 1). All Landsat image dates were selected from cloud-free scenes acquired during the dry seasons in order to account for seasonality or vegetation phenology in the classification. The three multi-date Landsat scenes were georeferenced to the Universal Transverse Mercator (UTM) map projection (zone 30 North).

Table 1. Summary of datasets used in the study

Images	Acquisition Dates	Path/Row	Remarks
TM	16/11/1986	197-53	Dry season
ETM+	02/10/2000	197-53	Dry season
OLI	31/01/2015	197-53	Dry season

Reference datasets were developed for classifier training (Table 2) and classification accuracy assessment for 2015. In addition, secondary reference data was obtained from Global Positioning System (GPS) points collected from october to november 2015.

Table 2. land use/cover classes

Land use/cover	Descriptions
Forest 	Crowned forests and gallery forests
Plantation/Tree savanna 	Relatively dense vegetation including mango trees, cashew trees and the teak plantations.
Settlement/Naked soil 	An area where there are permanent inhabitants, man-made structures and activities, such as towns. Area where the natural vegetation was eliminated on the broad wide ones and which overlaps with grass in the rainy season and dry season, strong confusion with the pieces of cultures to naked.
Culture(crop)/Fallow 	This class includes areas currently under crop, cultivated land or land being prepared for cultivation. These pieces are often with naked for the dry period. Zones little or none vegetalized made up of herbaceous savannas, pastures, food crops.
 Water	Reservoirs, river and flooded zones

3.2. EVALUATION OF RAINFALL EVOLUTION

The analysis of the inter-annual rainfall fluctuations is carried out from the calculation of Nicholson index. This index translates a surplus or a deficit for the year considered compared to the reference period selected. The abrupt and isolated fluctuations in rainfall indexes were filtered by the filter of Hanning. This method permits eliminating the seasonal variations in a given time series. This filter is carried out using following recommended equations (equation 1).

$$x_{(t)} = 0{,}06x(t-2) + 0{,}25x_{(t-1)} + 0{,}38x_{(t)} + 0{,}25x_{(t+1)} + 0{,}06x_{(t+2)} \qquad (1)$$

$3 \leq t \leq n-2$

x (t) is the total balanced rainfall of the term t (the rainfall index during the year t);
x (t-2) and x(t-1) are the principal totals rainfall observed of the two terms which precede the term t immediately;
x(t+2) and x(t+1) are the totals rainfall observed of the two terms which follow the term t immediately;
Balanced rainfall totals of the two first [x (1), x (2)] and the two last [x (n-1), x (n)] terms of the series are calculated through the following expressions (n is the size of the series) (equations 2, 3, 4 and 5) [13,14]:

$$x_{(1)} = 0{,}54x_{(1)} + 0{,}46x_{(2)} \qquad (2)$$

$$x\,(2) = 0{,}25x(1) + 0{,}5x_{(2)} + 0{,}25x_{(3)} \qquad (3)$$

$$x_{(n-1)} = 0{,}25x_{(n-2)} + 0{,}5x_{(n-1)} + 0{,}25x_{(n)} \qquad (4)$$

$$x_{(n)} = 0{,}54x_{(n)} + 0{,}46x_{(n-1)} \qquad (5)$$

Rainfall and hydrometric index calculation by Nicholson method made helped highlight surplus periods and periods in deficit within a time series. Nicholson index is expressed by the following equation (equation 6) [6].

$$Ip = \frac{Pi - Pmoy}{\sigma} \qquad (6)$$

Ip: rainfall index;
Pi: value of the annual rainfall of year i in mm;
Pmoy: inter-annual average value of rainfall in mm on the studied period;
б: inter-annual value of the standard deviation of rainfall over the studied period.

3.3 LAND USE/ COVER CLASSIFICATION AND CHANGE DETECTION

The methodology used in this study comprised four major components, namely data acquisition, pre-processing, land cover classification procedures, and accuracy assessment (Fig. 2). Five land cover classes were considered in this study: (1) Forest, (2) Plantation or tree savanna, (3) Culture or fallow, (4) Settlement or Naked soil and (5) Water. Detailed descriptions of these land cover classes are provided in Table 2. A supervised classification approach was used for land use classification. This technic provides in general best results. Colorful compositions have been used to identify all the types of land use. The colorful composition of the bands 4-5-7 for TM and ETM+ and the bands 5-6-7 for OLI was selected, for they present best discriminations of the types of land use. Several algorithms exist within supervised classification and allow to reproduce the reality of the field as well as possible perceived through the satellite images. The maximum likelihood classification was chosen in the framework of this study. The classification permits to transform the images in thematic maps [15].

Classification evaluation was carried out by the confusion matrix which permits to obtain the precise details of the process. Two classification assessment indexes were calculated: the overalls accuracy characterizes the proportion of well classified pixels; the Kappa index characterizes the relationship between the well classified pixels and the total of the probed pixels. The diagonal of the confusion matrix represents the percentages of the well classified pixels. In addition to the indexes, the field work data were also used for the validation. Then, we used the median filter 3x3 of ENVI 5.1 Convolution and Morphology tool to improve the classified images.

The algorithm chosen for the detection of the changes is the difference of the multi-date's images [16, 17]. The three images used were replaced by the classified images.

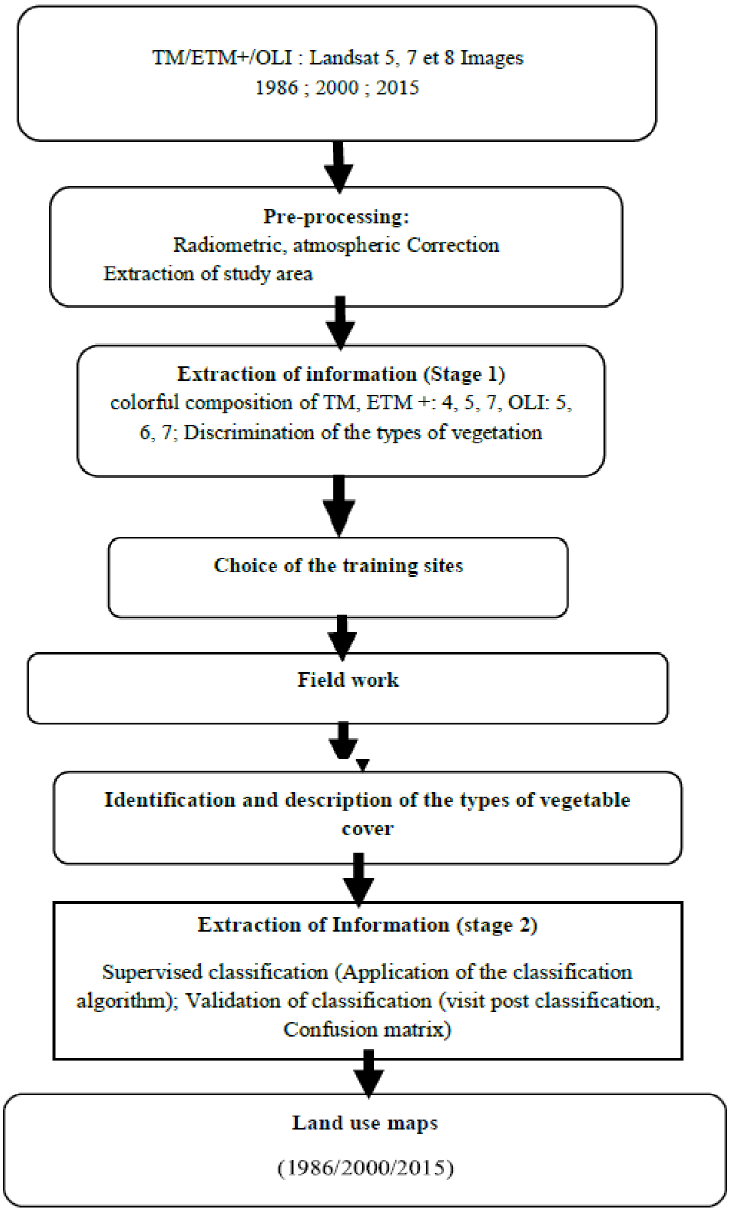

Fig. 2 : land use classification flow diagram

3.4. EVALUATION OF LAND USE DYNAMICS

The data obtained from the interpretation of each Landsat image TM (1986), ETM+ (2000) and OLI (2015) were analyzed and compared. Thus, for each unit of land use, the annual evolution rate is calculated according to the following formula (equation 7) [6]:

$$T_{annual} = \frac{V_{i2015} - V_{i1986}}{P} \quad (7)$$

Vi_{2015} represents the statistics value of the layer i in 2015;
Vi_{1986} the statistics value of the layer i in 1986;
P is the period of observation between 1986 and 2015 which is twenty-nine years.
This formula permit to make a diachronic analysis of land use dynamics on the study area.

IV. RESULTS

4.1. INTER-ANNUAL RAINFALL VARIABILITY AT THE WEATHER STATION OF KORHOGO

The evolution of the annual rainfall index at the weather station of Korhogo shows an alternation of wet and dry periods (figure 3).

- Positive indices correspond to wet periods (from 1984 to 1987 and from 2008 to 2014). The period of 1984-1987 has an inter-annual average rainfall of 1322 mm and the period of 2008-2014, 1359mm. These periods are characterized by rainfall indices ranging between 0 and 2, a mostly moderated to strong wet period.
- Negative indices indicate a dry period (from 1988 to 2007) with an inter-annual rainfall average of 1179 mm. Indices from -1 to -2 show a moderate to strong drought period while extreme droughts occurred in 1983 and 2000-2001.

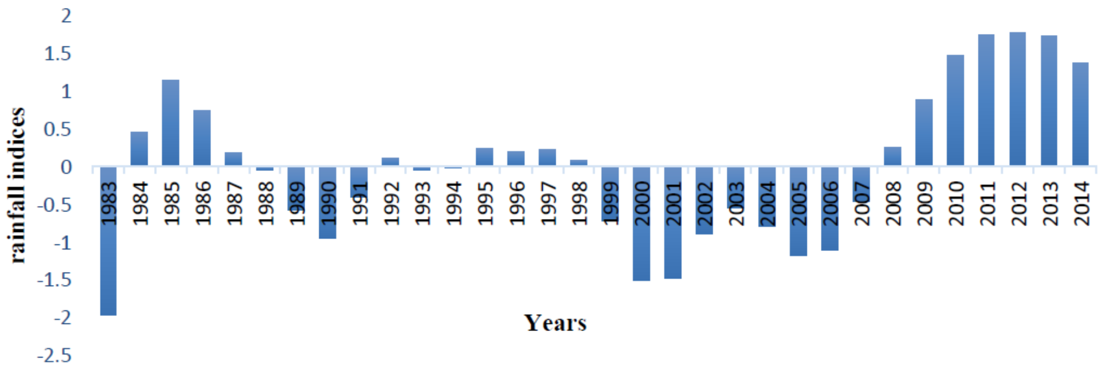

Fig. 3: Annual rainfall evolution at the weather station of Korhogo from 1983 to 2014

4.2. SUPERVISED CLASSIFICATION AND EVALUATION

The five classes of land use were characterized as: the forests, Plantation/ trees savanna, Settlement/ open soil, crop/fallow and water reserves. These different classifications were evaluated using the Confusion matrix represented by tables 3, 4 and 5. They were prepared calculating the overall accuracy of classification and the Kappa index using field data. In the diagonal of these tables, the percentage of well classified pixels is posted and the rest shows the percentage of badly classified pixels.

Table 3. confusion matrix of the classification of image of 1986

Classes	Forest	Plantation/Tree savanna	Settlement/Naked soil	Culture(crop)/fallow	Water
Forest	100	1,11	0,00	0,00	0,23
Plantation/Tree savanna	0,00	69,93	0,00	0,00	8,75
Settlement/Naked soil	0,00	23.99	98.38	0,87	1,17
Culture (crop)/ Fallow	0,00	4.98	1,62	99,13	1,87
Water	0,00	0,00	0,00	0,00	87,98
Total	100	100	100	100	100

Overall accuracy: 84,63%; Kappa index: 0,78

The confusion matrix shows a reasonable classification of the satellite image. But there were some confusions and the most significant is: 23% of open soil was confused with plantation/ trees savanna class.

Table 4. Confusion matrix of the classification of image of 2000

Classes	Forest	Plantation/Tree savanna	Settlement/Naked soil	Culture/Fallow	Water
Forest	100	0,00	0,16	0,00	0,00
Plantation/Tree savanna	0,00	44,65	5,78	0,32	0,00
Settlement/Naked soil	0,00	16,05	86,23	0,32	0,47
Culture/Fallow	0,00	39,30	7,84	99,36	0,00
Water	0,00	0,00	0,00	0,00	98,53
Total	100	100	100	100	100

Overall accuracy: 87,04%; Kappa index : 0,75

The analysis of this confusion matrix shows that there are strong confusions between crop/fallow and plantation/trees savanna classes: 39.30% of the crop/fallow class was confused with the plantation/ tree's savanna class.

Table 5. Confusion matrix of the classification of image of 2015

Classes	Forest	Plantation/Tree savanna	Settlement/Naked soil	Culture/Fallow	Water
Forest	99,77	0,00	0,03	0,00	0
Plantation/Tree savanna	0,00	99,26	0,11	0,00	0
Settlement/Naked soil	0,00	0,55	98,05	1,63	1,17
Culture/Fallow	0,23	0,18	1,81	98,37	0,00
Water	0,00	0,00	0,00	0,00	98.83
Total	100	100	100	100	100

Overall accuracy : 98,30% ; Kappa index : 0,96

The confusion matrix indicates a best classification of the satellite image. No major confusion recorded.

4.3. LAND USE DYNAMICS

The different processes helped prepare land use maps in general and vegetative cover maps in particular of the study area from 1986 to 2015. During twenty-nine years, there is a clear trend in land use modification, interpreted in a qualitative and quantitative way. Over the years, the study area remained dominated by the crop/fallow class. In 1986, Plantation/savanna trees class showed a strong concentration around the town of Korhogo and crop/fallow in the North. Forest and water classes are fairly well represented and one notes a considerable reduction in these two classes.

The results associated to the different surfaces during the three periods are presented in term of surface (Table 6) and percentage (Table 7).

Table 6. Surfaces of land use classes in 1986, 2000 and 2015 on the scale of study area

Classes	1986 (Km^2)	2000 (Km^2)	2015 (Km^2)
Forest	153.5	48.9	43.2
Plantation/Tree Savanna	141	327	392.3
Settlement/Naked soil	196.7	452.6	359.9
Culture (crop)/Fallow	1005.3	666.6	702
Water	3	4.3	2

Total surface treated: 1499,5 km^2.

Table 7. Percentages of land use classes in 1986, 2000 and 2015

Classes	1986 (%)	2000 (%)	2015 (%)
Forest	10.23	3.26	2.88
Plantation/Tree Savanna	9.4	21.8	26.16
settlement/Naked soil	13.11	30.18	24
Culture (crop)/Fallow	67.04	44.45	46.81
Water	0.2	0.28	0.13

4.3.1. LAND USE DYNAMICS FROM 1986 TO 2000

The analysis of the figure 4 and 5 shows two trends in the evolution of the different classes of land use between 1986 and 2000. An increase of plantation/trees savanna (12.4%) and naked or open soil (17.07%) and but water does not undergo significant change (0.08% of progression). One observes a decrease of the forests (-6.97%), and Crop/fallow (-22.59%). The rates of variation in different classes of land use from 1986 to 2000 are contained in table XIII below. The increase in the Settlement/ naked soil class could be due to the drought between 1986 and 2000, observed through the rainfall indexes.

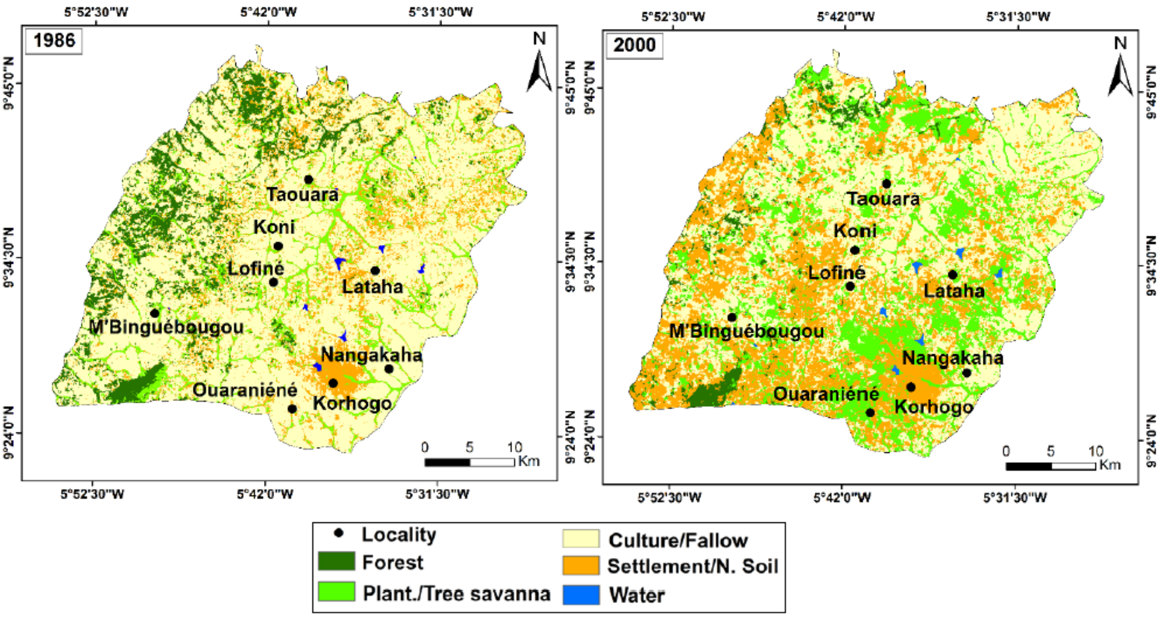

Fig. 4: Land use maps for 1986 and 2000

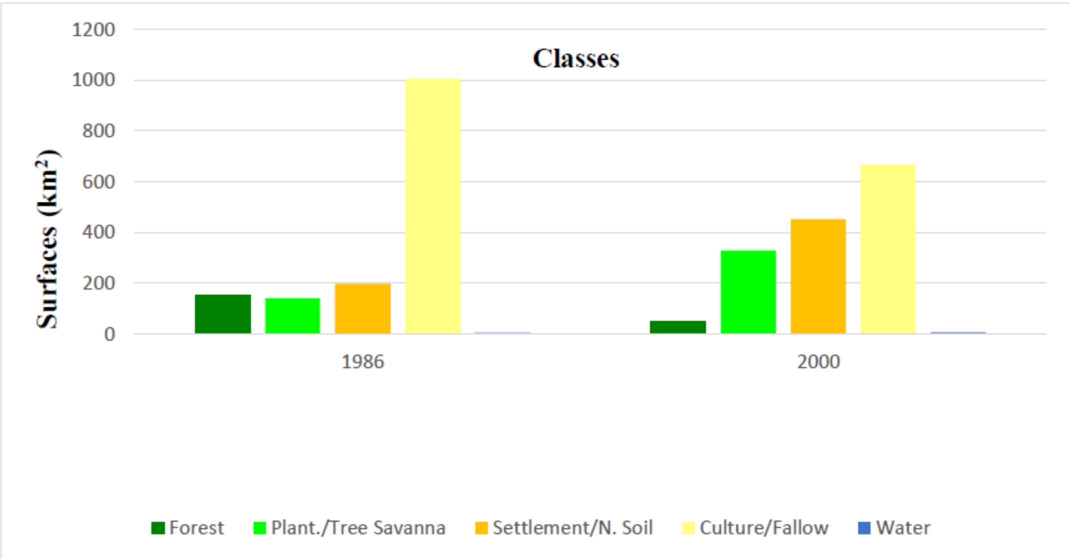

Fig. 5: Evolution of the surfaces of land use classes between 1986 and 2000

Table 8. Rate of variation of the classes of land use between 1986 and 2000

Classes	Tg (%)	Tan (%)
Forest	-6,97	-7,47
Plantation/Tree Savanna	12,4	13,28
Settlement/Naked soil	17,07	18,27
Culture/Fallow	-22,59	-24,19
Water	0,08	0,09

Total surface treated: 1499.5 km^2
Tan: annual average rate of evolution from 1986 to 2000;
Tg: rate of evolution within the same class from 1986 to 2000

The results of the interpretation of table 8 reveal annual regressions of -7.47%, -24.19% respectively for the forest and fallow classes. In parallel one notes annual average progressions of 13.28%, 18.27% and 0.09% respectively for the classes of plantation/trees savanna, Settlement/naked soil and of water. The increase took place with the detriment of forest surfaces and Culture/Fallow. The evolution rates within the same class vary with a great amplitude. The greatest variations were observed on Culture/Fallow class followed by the naked soil class. The increase in the water class is due to a rehabilitation of the dams of the study area in 1992 including that of Natiokobadara near the town of Korhogo.

4.3.2. LAND USE DYNAMICS FROM 2000 TO 2015

Land use dynamics of 2000 and 2015 is presented by figures 6 and 7 below. The figures 6 and 7 show a regressive trend of forest class (from 3.26% to 2.88%) and naked soil class which passes from 30.18% to 24%, the water class passes from 0.28% to 0.13%. Then, one notes a progressive trend of the plantation or tree savanna space (from 21.8% to 26.16%) and culture or fallow space.

The variation rates of the different classes of land use from 2000 to 2015 are represented by the table 9.

The maps of land use of 2000 and 2015 through Landsat ETM+ and OLI images classification are presented by figures 16 below.

The analysis of the map resulting from the satellite image processing (figure 6) and the graphic of the figure 7 shows a regressive trend of forest class (from 3.26% to 2.88%) and naked soil class which passes from 30.18% to 24%, the surface of the water class passes from 0.28% to 0.13%. Then, one notes a progressive trend of the surface of plantation or trees savanna (from 21.8% to 26.16%) and of that of spaces of culture or fallow.

The variation rates of the different classes of land use from 2000 to 2015 are represented by the table XIV.

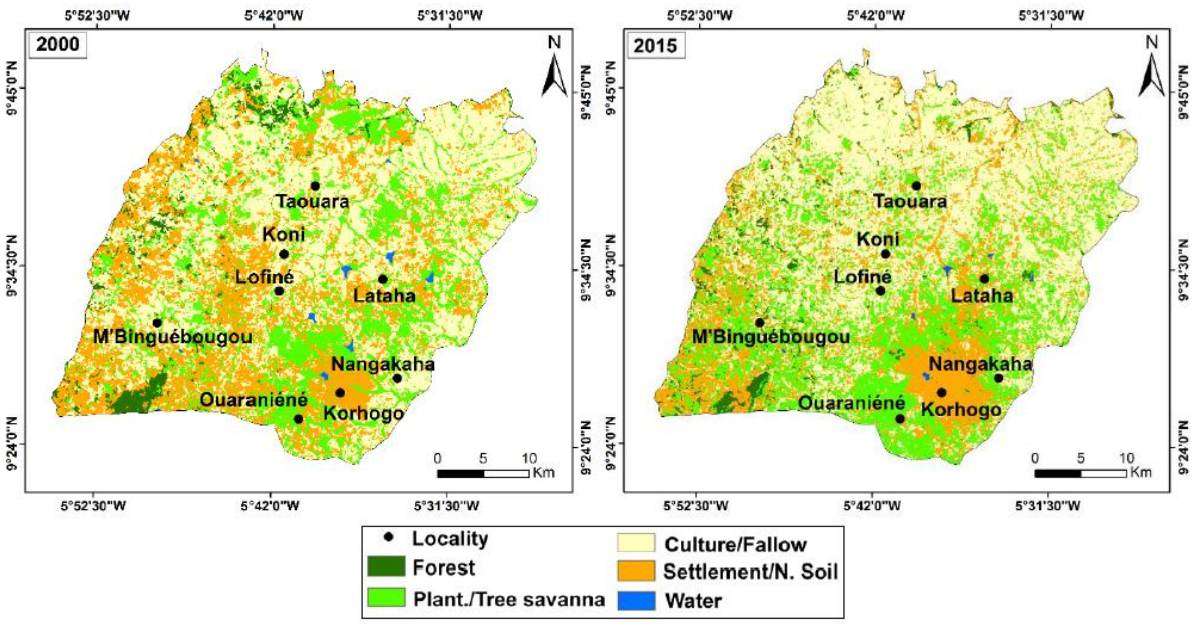

Fig. 6: Land use maps for 2000 and 2015

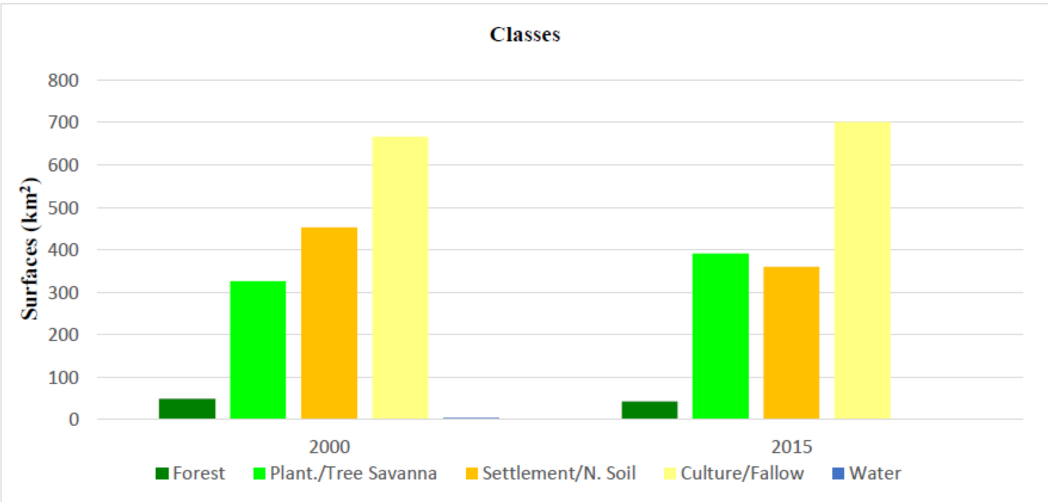

Fig. 7: Evolution of the surfaces of land use classes between 2000 and 2015

The table 9 shows an annual average increase in the surface of plantation/trees savanna from 4.6% and that of spaces of fallow of 2.5%. One notes an annual average reduction of 0.4%, 6.6%, 0.16% respectively for the surfaces of forest, Settlement/naked soil classes, and of the water class. The regression of the naked soil can be related to the succession of wet periods these last years. Twenty-four years after their rehabilitation, the dams do not manage to durably preserve stored water.

Table 9. Rate of variation of the classes of land use between 2000 and 2015

Classes	Tg(%)	Tan (%)
Forest	-0,4	-0,4
Plantation/tree savanna	4,3	4,6
Settlement/Naked soil	-6,18	-6,6
Culture/Fallow	2,36	2,5
Water	-0,15	-0,16

Total surface treated: 1499.5 km^2

Tan: annual average rate of evolution from 2000 to 2015;

Tg: rate of evolution within the same class from 2000 to 2015.

4.3.3. EVOLUTION OF LAND USE FROM 1986 TO 2015

The global evolutionary trends noted in the land use dynamics from 1986 to 2015 are represented by figure 8. The comparison of the states of land use of 1986 and 2015 gives an idea of the changes operated in the different landscapes. The analysis of figure 9 indicates a reduction in the surfaces from 10.23% to 2.88%, from 67.04% to 46.81%, from 0.2% to 0.13% respectively of the forest, cultures or fallow and water classes. In parallel, one observes a significant increase in the surfaces of plantation or trees savanna and Settlement/naked soil which pass respectively from 9.4% to 26.16% and 13.11% to 24%. The variation rates of the different classes of land use observed in the whole of the period of study (1986-2015) are represented by table 10.

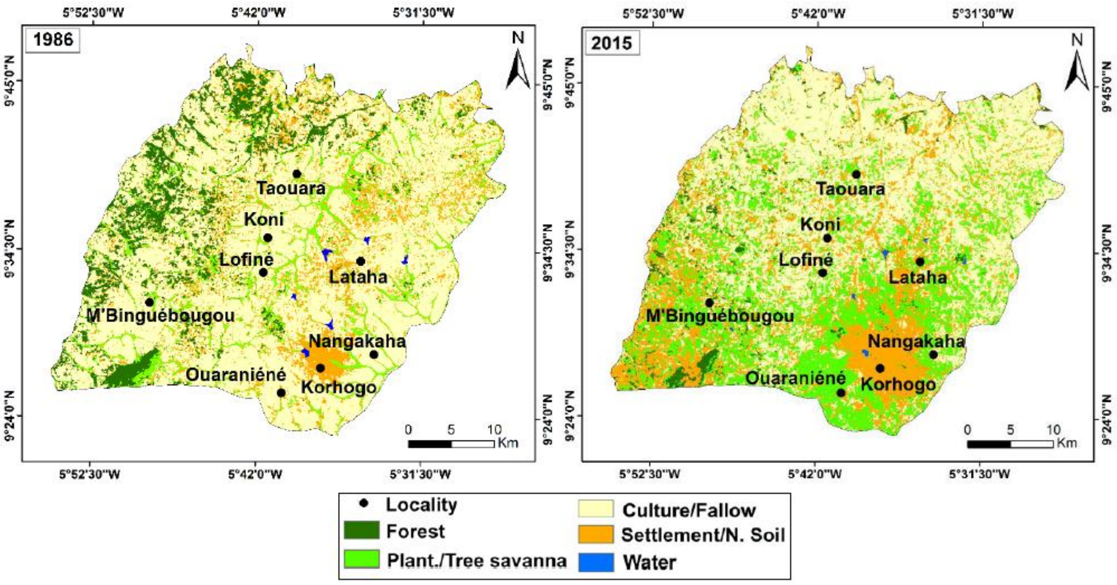

Fig. 8: Land use maps for 1986 and 2015

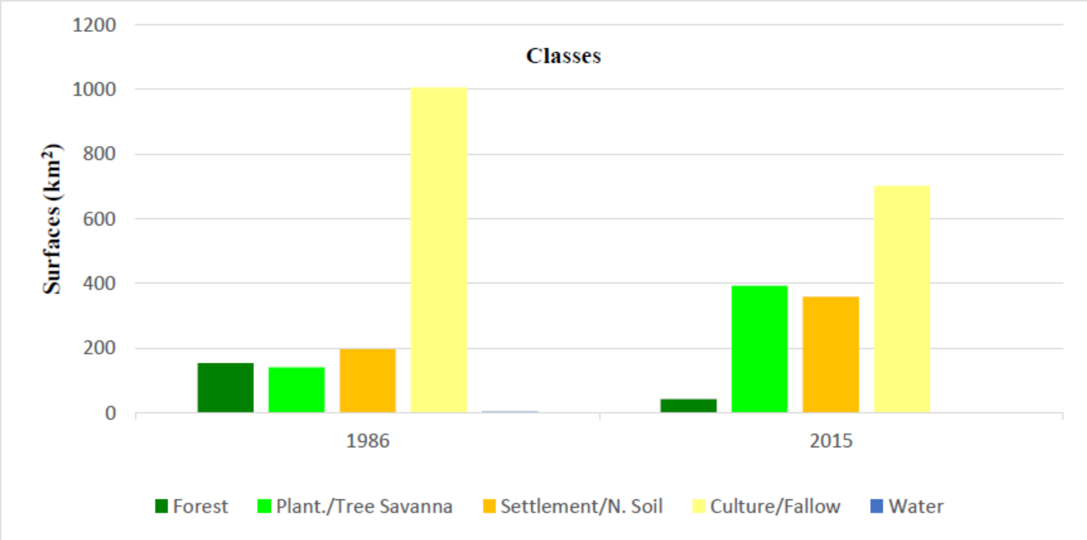

Fig. 9: Evolution of the surfaces of land use classes between 1986 and 2015

The table 10 indicates a negative annual average evolution rate of forest, fallow and water classes. The water regressed of 0.07%, the forest of 7.87% and culture or fallows space has the highest rate of regression (21.66%). The regression of forest space is probably related to the abuse of the wood species and culture/fallow area is related to the expansion of the plantations of mango trees, cashew trees and teak. It seems to exist a correlation between the reduction of the forest space and the fluctuation of rainfall. On the other hand, one notes a progression of the plantation/tree savanna and settlement or naked soil respectively of 17.95% and 11.65%.

The analysis of the table 10 indicates a negative annual average evolution rate of forest, fallow and water classes. The water regressed of 0.07%, the forest of 7.87% and culture or fallows space has the highest rate of regression (21.66%). The regression of surfaces of forest is probably related to the abuse of the wood species and that of Culture/fallow area is related to the expansion of the plantations of mango trees, cashew trees and teak. A correlation seems to exist between the reduction of the surface of the forest and the fluctuation of rainfall. On the other hand, one notes a progression of the plantation/tree's savanna and naked soil respectively of 17.95% and 11.65%.

The increase in the area occupied by the town of Korhogo has more than tripled (figure 8). This increase is related to the demographic pressure, which is at the base of some anthropogenic practices that weakens the environment and exposes the ground. In particular, the clearing of vegetation covered zones, especially the lowlands (basfonds) for cropping (favored because of access to moisture) around the town of Korhogo and the villages.

A return of vegetation around the town of Korhogo is observed in 2015. Indeed, that is characterized by a resumption of rainfall from 2009. But this return to wetter conditions does not seem to be accompanied by an improvement of environmental conditions: in the north of the sub-prefecture, the vegetation is not only less dense than that of 1986, but its composition also changed. Small surfaces of forest yielded to a grassy savanna. The inhabitants of the villages affirm that that was noted in the area after the successions of dryness around years 2000 and also following the removal of the wood species. The increase in vegetation near the town of Korhogo and in certain localities (like Lataha, M'Binguebougou and Koni, with the opening of the roads) is mainly related to the development of teak plantations and the creation of the crowned forests. This tree (teak) was introduced into the area by SODEFOR (Société de Développement des Forêts) within the framework of the policies of afforestation and also by certain peasants. For lack of follow-up by the local population, these operations of afforestation tend to fail.

The extension of the perennial cultures (cashew trees and mango trees) in the South of the study area is explained by the favorable conditions to their development in this area. This vegetative settlement is visible on the land use map of 2015 (figure 8).

Table 10. Rate of variation of the classes of land use between 1986 and 2015

Classes	Tg(%)	Tan(%)
Forest	-7,35	-7,87
Plantation/tree savanna	16,76	17,95
Settlement/naked soil	10,88	11,65
Culture/fallow	-20,22	-21,66
Water	-0,06	-0,07

Total surface treated: 1499.5 km^2
Tan: annual average rate of evolution from 1986 to 2015;
Tg: rate of evolution within the same class from 1986 to 2015.

V. DISCUSSION

Rainfall recession was generally observed in West Africa and particularly in Côte d'Ivoire [18, 19]. This rainfall reduction with successive of drought periods since the end of the sixties involved modifications in the different agro-climatic area and marked the beginning of the hydrous stress for vegetation [20]. This phenomenon was observed in a general way in West and Centrale Africa [21]. Indeed, an isolated year of drought, even extreme can be less dramatic than a succession of two years (or more) of moderate drought [21]. These drought periods reduce the availability of useful water and nutriments, limiting the physiological working of the plants. The persistence of the drought is a major risk. Several studies showed the influences of the drought on the flora. Some highlighted that the repeated drought in the seventies and eighties caused directly, in particular in Africa, the mortality of the woody species of the significant ecosystems. Indirectly, the prolongation of the heat and the draining periods of the environment induce an activation of physiological stresses for the tree which could again reduce its systems of defense against the pathological attacks [21]. The years of weak productions of biomass correspond to the years in deficit on the rainfall level [22].

The overalls accuracy obtained in this work are 84.63 % (1986), 87% (2000) and 98 % (2015). The Kappa indexes of the confusion matrix are 0.78 for 1986, 0.75 for 2000 and 0.96 for 2015. The results of this analysis are statistically acceptable [23]. So, the present classification with five classes is acceptable and allows to evaluate land use changes from 1986 to 2015. Nevertheless, the overalls accuracy of the treatments estimated at 84.63 (1986), 87% (2000) and 98% (2015), are considered to be acceptable [6]. [24] obtained overalls accuracy of 92% and 95% respectively in 1986 and 2000, results which are close to those obtained in this work. [25], as for him obtained an overall accuracy of 79.16% and 97.6% in 1986 and 2007, by treating images Landsat and Spot XS [26]. Leroux (2012) [27] obtained in his work overalls accuracy of 99% and 96% respectively in 1986 and 2000 and Kappa indexes of 0.98 (1986) and 0.93 (2000) by classifying Landsat images covering a space close to our study area.

The settlement or naked soil, tree savanna, culture or fallow classes shows some errors of confusion. The difficulty of discriminating these classes visually can be due to similar spectral signatures. This situation explains the confusion between the cultures or fallow and tree savanna or plantation classes. Savanna has a canopy cover of about 2 à 20% [28]. An increase in the plantations or tree savanna is observed. This report seems correlated with the climatic conditions highlighting a standardization of rainfall since 2009. This trend can be also explained by the reinforcement of the conservation and protection measures of the vegetable cover in the study area (Afforestation). This class is mainly found in the Southern part of the study area. In the same way, the plantations (cashew tree, mango tree and teak) can be associated to this class and it constitutes the vegetation most largely represented. This situation explains the errors of confusion which exist between the two classes (culture or fallow and tree savanna). However, the values of these recorded errors of confusion are low. Indeed, apart 39.30% of error of confusion which exists between the culture or fallow class and the plantation or tree savanna class, no other error exceeds 25%. These errors are acceptable as none of these errors is above 70% which are the limiting value [29]. The analysis of land use dynamic from 1986 to 2015 shows that the naked soil and the teak plantations, mango tree and of cashew tree increase in a significant degree, in opposition to forest, water reservoir and culture or fallow spaces which regress clearly. This analysis is significant as it permits to understand the changes occurred in the land use on the one hand, and them causes on the other hand. The rates of regression noted on forest and the water level (-0.07%) (-7.87%) are low contrary to that noted on the level of the culture or fallow (-21.66%). Parallel to these regressions, one notes that the savanna and the annual culture spaces are replace more and more by the naked soil and the plantations with annual average rates of evolution respective of 11.65% and of 17.95%. One can conclude that this degradation would be due to the natural phenomena (rainfall variability) and/or with the anthropogenic pressures (bush fires, creation of new plantations, etc.) [30]. Moreover, the reduction of the water levels seems to be related on the impact of rainfall spatial and temporal variability.

VI. CONCLUSION

Rainfall indices analysis from 1983 to 2014 show an alternation of two rainfall trends: wet period and dry period. The general trend of rainfall indices is down with a permanent worsening of negative values from 1988 to 2007 which indicate drought mainly moderate and sometimes strong in the seventies in West Africa.

The follow-up of the vegetable cover of the sub-prefecture of Korhogo led to perform the mapping of land use using Landsat satellite images TM (1986), ETM+ (2000) and OLI (2015). The method of supervised classification resulted in discriminating five classes of land use (forest, plantation/tree savanna, settlement/naked soil, culture/fallow and water) in the study area. These classes occupy respectively 153.5 Km^2 (1986) and 43 km^2

(2015), 141 km^2 (1986) and 392.3 km^2 (2015), 196.7 km^2 (1986) and 359.9 km^2 (2015), 1005.3 Km^2 (1986) and 702 (2015), 3 km^2 (1986) and 2 km^2 (1986). The overalls accuracy obtained are 84.63% (1986), 87% (2000) and 98% (2015). The Kappa index are 0.78 in 1986, 0.75 in 2000 and 0.96 in 2015. The maps made helped identify a temporal and spatial evolution of land use in the study area. Two trends in the evolution of the vegetable cover were identified. A progressive trend is expressed on the level of the plantation/tree savanna and settlement/naked soil classes respectively 17.95% and 11.65%. The regressive trend relates to the dominated classes by the forest (-7.87%) and culture/fallow (-21.66%) and water (-0.07 %). On the whole, the study area is marked by a strong anthropogenic pressure and a degradation of rainfall conditions which involved a modification of the vegetable cover from 1986 to 2015; indeed, the sub-prefecture of Korhogo knows an accelerated demographic growth. Jointly with this phenomenon, the climatic modifications in progress also involve deep environmental upheavals. Moreover, the farming technics, such as the practice of the slash and burn technics are unfavorable to the environment. In order to formulate sustainable land use management strategies in the study area, timely and up-to-date land cover information is required. Recent advances in remote sensing technology have improved land cover mapping in tropical areas. The monitoring of the vegetable cover in Northern Côte d'Ivoire was essential as a priority for the political decision makers as for the scientists and the local communities.

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