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Dynamics of the Exploitation of the Alluvial Plain of the River Zotto in the Finage of Zépréguhe (Midwest, Cote D'ivoire)

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ABSTRACT

Located in the middle of the Ivorian forest zone, the alluvial plain of the Zotto River has been undergoing profound spatiotemporal changes for decades due to the emergence of anthropic activities that are constantly degrading the vegetation cover. The objective of this study is to map the dynamics of the land use of the said plain using remote sensing and GIS tools in order to better understand the evolutionary trend of the land use units in a context of sustainable management of existing natural formations. The achievement of this objective required the mobilisation of cartographic data (satellite images from 1986, 2000 and 2021) and field data (topographic surveys, documentary research, direct observation and questionnaire survey). The main results of the cartographic processing of the images reveal that the plain is undergoing an increasingly accelerated anthropogenic process. This anthropogenic process results in the saturation of the land on the one hand and its scarcity for agricultural activities on the other. In addition, our study highlights the multiple land conflicts encountered in Zépréguhé following the finage. Finally, it shows that land competition and other forms of use of the alluvial plain of the Zotto River are harbingers of deforestation.

Keywords: Dynamics, exploitation, alluvial plain, Zotto river, Zépréguhé.

Résumé: Située en pleine zone forestière ivoirienne, la plaine alluviale de la rivière Zotto connait depuis des décennies de profondes mutations spatiotemporelles en raison de l’émergence des activités anthropiques qui ne cessent de dégrader le couvert végétal. L’objectif de cette étude est de cartographier à l’aide d’outils de télédétection et SIG, la dynamique de l’occupation du sol de ladite plaine afin de mieux appréhender la tendance évolutive des unités d’affectation du sol dans un contexte de gestion durable des formations naturelles existantes. L’atteinte de cet objectif a nécessité la mobilisation des données cartographiques (images satellitaires de 1986, 2000 et 2021) et des données de terrain (relevés topographiques, recherche documentaire, observation directe et enquête par questionnaire). Les principaux résultats issus des traitements cartographiques des images révèlent que la plaine subit une anthropisation de plus en plus accélérée. Ce processus anthropogénique a pour conséquence la saturation des terres d'une part et leur raréfaction pour les activités agricoles d'autre part. En outre, notre étude met en évidence les multiples conflits fonciers rencontrés à Zépréguhé suite au finage. Enfin, elle montre que la compétition foncière et les autres formes d'utilisation de la plaine alluviale de la rivière Zotto sont des signes avant-coureurs d'une déforestation.

Mots-clés: Dynamique, exploitation, plaine alluviale, rivière Zotto, Zépréguhé.

INTRODUCTION

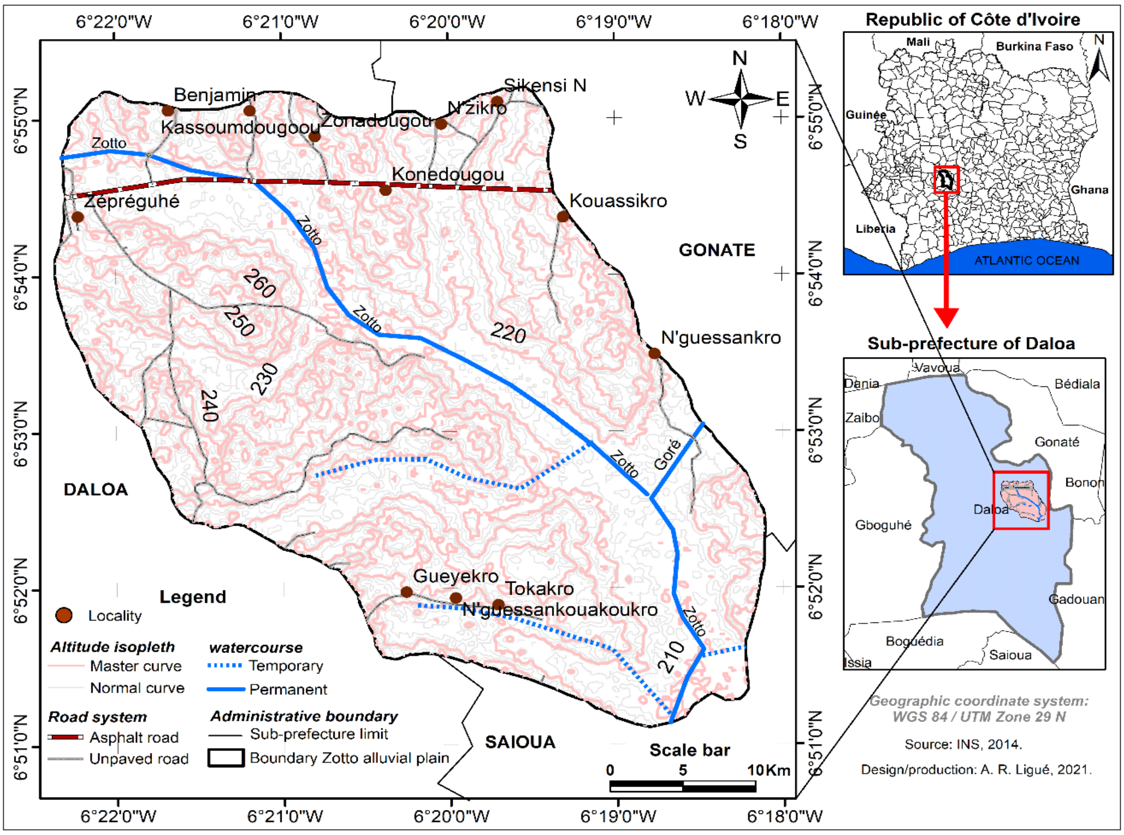
On the eve of independence, Côte d'Ivoire based its economy on agriculture, particularly coffee and cocoa. This political choice resulted in the reduction of forest cover and the development of cash crops, hence the human hold on the natural physical environment. In Central-Western Côte d'Ivoire, this human influence is characterised by an agricultural dynamic resulting from the availability of land and the migration of non-native and native populations. This is followed by a crisis phase, which is reflected in the pressure on land caused by demographic growth, leading to the saturation of arable land over the years. To compensate for this lack of land, the population turned to wetlands, plains and lowlands. Thus, wetlands, which were previously neglected, are increasingly coveted by farmers and integrated into the spaces dedicated to agricultural production systems (A. R. Ligué. 2019, p. 19). Indeed, these vast areas that were abandoned by farmers for farming because of their hydrological constraints are becoming popular thanks to their natural assets and the development strategies they have developed. In so doing, it is becoming an area of strong human influence with numerous food and market crops as well as cash crops such as cashew nuts and rubber trees (N.H.L. Kouassi, 2019, p32). Thus, several crops such as cashew nuts, rubber trees as well as food crops are grown in the alluvial plain of the Zotto River, which is exploited by the population of Zépréguhé. In fact, it abounds in a set of resources whose development is becoming an imperative necessity for the development, intensification and diversification of agricultural production. This situation leads to various assessments in view of the causes invoked to justify this anthropic pressure on the occupation and use of the alluvial lands of the Zotto River. This article aims to assess the level of anthropogenic pressure on the alluvial plain of the Zotto River. The analysis is based on bibliographical research, which provides elements for explaining the evolution of this occupation by placing it in its historical context, field observation, surveys, statistical data and cartography.

1. Presentation of the study framework

The study was conducted in the alluvial plain of the Zotto River in the Zépréguhé area, located in the Daloa sub-prefecture in west-central Côte d'Ivoire. Covering an area of 3,870 hectares, the alluvial plain of the Zotto River lies between 6°51' and 5°55' North latitude and between 6°18' and 6°22' West longitude (Figure 1). Geographically, it is bounded to the west by the town of Daloa, to the east by the sub-prefecture of Gonaté and to the south by the town of Gadouan.

Demographically, the population working in the alluvial plain is both composite (indigenous and non-indigenous) and has agriculture, livestock breeding and trade as its main activities (A. R. Ligué, 2019, p.8). However, the size of the resident population in the Zépréguhé finage is 5,372 inhabitants, i.e. 3,022 men against 2,350 women with a sex ratio of 128.6 (INS-SODE, 2014, p.7).

Figure 1: Location of the Zotto River alluvial plain



Overall, the topography of the area is dominated by flatness. The highest altitudes are around 250 metres and the lowest, 210 metres (Figure 1). The soils are hydromorphic and ferralitic, located respectively on the lower and upper slopes of the plain. Thanks to the hydromorphic soils, the area benefits from hydrophilic vegetation during at least part of the year. In terms of climate, the said sector is confronted with a humid tropical climate characterised by four seasons, two of which are dry (from December to March and from July to August) and two rainy (from April to June and from September to November).

2. DATA AND METHODS

2.1. Study data

The data used for the study consisted mainly of Landsat satellite images, SRTM images, a Google Earth extract, basic cartographic data and field data.

2.1.1. Landsat satellite data and SRTM images

The satellite images used were downloaded free of charge from www.earthexplorer.usgs.gov. They come from the Landsat series for the years 1986, 2000 and 2021 from the TM, ETM+ and OLI sensors respectively (Table 1). The months of January/February were chosen because of the climatic seasons and the availability of good quality images (low cloud cover). The choice was also based on the spectral (images taken at different wavelengths), spatial and temporal (good repeatability) characteristics of the images, allowing for good land cover mapping.

Table 1: Characteristics of satellite images.

Date of shooting	Sources	Sensors	Strips used	Spectral resolutions
18/01/1986	Landsat TM	TM (Landsat 5)	3, 4, 5	30 m
02/02/2000	Landsat ETM+.	ETM+ (Landsat 7)	3, 4, 5	30 m
10/01/2021	Landsat OLI	OLI-8 (Landsat 8)	5, 6, 7	30 m

Source : BAT files 1986, 2000 and 2021.

In addition, available since 2014, SRTM images have also been uploaded to https://srtm.csi.cgiar.org/, notably on 08/10/2021. These images have a spectral resolution of 30 m. The particularity of these images is to provide information on the topography and hydrography of a given region.

2.1.2. Base and field mapping data

The map data used are shapefiles of the road and water network, administrative boundaries and localities. These data were generated by the NDELB/NIGC in 2013. The boundaries of the floodplain were obtained from a Google Earth extract dating from 2022.

In addition, field data were collected with a Garming GPS receiver on the plain. The operation consisted of taking geographical coordinates of the different land uses of the lower slopes, mid-slopes and upper slopes. A questionnaire was sent to the farmers working on the plain. The choice of respondents took into account their agricultural activities (perennial crops, annual crops, market gardening) and their origin (indigenous, non-indigenous). Thus, 80 farmers were interviewed on this basis. The sampling method adopted was the purposive method.

2.2. Data processing methods

2.2.1. Pre-processing of Landsat images

The satellite images were pre-processed using Envi 5.3 software. These operations consisted of correcting a certain number of variations in the distribution of the data caused by atmospheric conditions and sensor calibration. Indeed, the images acquired were provided with a geometric correction (WGS 84 zone 29N) of Level 1T. Thus, only the radiometric and atmospheric corrections (FLAASH module based on radiance) associated with the extraction of the study area were carried out.

2.2.2. Landsat image processing

The processing of the images follows several steps, the first of which is the determination of the choice of colour compositions. The colour compositions of bands 3-4-5 for the Landsat TM and ETM+ images, then 5-6-7 for OLI, were selected. They were used as a support for field prospection. To carry out the supervised classification, training plots representative of the units identified on the images were used to judge the separability of the land use classes. Thus, a typology of surface states could be identified, namely forest, water body, food crop/fallow, perennial crop and the "Buildings/bare soil" mosaic (Table 2). In addition, samples were selected by class and distributed homogeneously over the different images to be classified.

The classification algorithm used is the Support Vector Machine (SVM). This algorithm has been adopted for its efficiency in classifying complex data and obtaining good results. The SVM method is a supervised classification method that solves discrimination and regression problems. The process for this classification using ENVI 5.3 software is as follows: Classification > Supervised > Support Vector Machine (SVM).

The improvement of the quality of the classified images required a homogenisation operation which consists in applying morphological operators. For this purpose, a majority filter was used to reduce the salt and pepper effect. For this, a dilation operation followed by an erosion operation with a median filter of size 3×3 was applied.

Table 2: Identification of land use classes.

The main features of land use	Classes
Natural area	Forest Water body
Humanised space	Building/bare ground Perennial crop Food crop/fallow

Source: Fact-finding mission, December 2021.

2.2.3. Evaluation of Landsat Image Classification

The results of the classifications were evaluated using two indicators of the

Confusion Matrix, namely the overall accuracy and the kappa coefficient. The global precision, between 0 and 100%, makes it possible to evaluate the precision of the classified pixels in relation to the total number of pixels in the test zones. The kappa coefficient, between 0 and 1, is used to evaluate the overall reliability of the classification results in relation to the reference data.
In the present study, the image classification is validated when the kappa values are greater than or equal to 80%. Thus, following this validation, the land use maps of the Zépréguhé alluvial plain in 1986, 2000 and 2021 were produced.

2.2.4. Field data processing
The data collected from the farmers surveyed were processed using an Excel spreadsheet. From the dynamic cross-tabulations, statistics on the distribution of farmers according to their origin and mode of access to land in the plain were elaborated.

2.3. Statistical analysis of land use units from 1986; 2000 and 2021.
The statistical analysis of the land use dynamics involves a comparison of the areas of the land use units for the years 1986, 2000 and 2021 respectively. This analysis was carried out by generating the areas of the land use classes from the attribute tables of the classified images, using the Calculate Geometry tool in ArcGis 10.8 software.
The characterisation of the evolution of land use types between 1986 and 2021 was possible by calculating two rates. The first is the overall rate of change and the second is the average annual rate of change/regression.

$$\mathbf{Tx=[(SP2-SP1)/SP1]x100}$$

With **SP1**= Area at initial date and **SP2**= Area at final date

The rate of change estimates the proportion of gain (positive value) or loss (negative value) of land use areas.

$$\mathbf{Tc = [(SP2 / SP1)1/t - 1] x 100}$$

SP2: area at final date; **SP1:** area at initial date; t: difference in years between 2 dates.
Tc is positive for increasing land use classes and negative for decreasing ones. In order to better understand the changes during the period 1986 to 2021, this rate has been calculated.

2.4. Assessment of land use changes
The results of the map output from the supervised image classification were compared, class by class, to assess changes. Crossing the land cover maps in pairs to provide land cover unit detection maps using change matrices. The columns of these matrices represent the area of each class in the most recent year, while the rows represent the area in the previous year.

3. RESULTS

3.1. Evaluation of the classification of satellite images from 1986, 2000 and 2021
The supervised classifications of the satellite images of the years 1986, 2000 and 2021 of the study area were evaluated thanks to the confusion matrices presenting the global precision and the Kappa coefficient. Overall, the Kappa coefficients obtained are above the threshold set in the study (i.e. 80%). However, some confusions are perceived in the matrices.

- **Confusion matrix analysis of the TM image classification, 1986**

The confusion matrix of the supervised classification of the TM image of the year 1986 provided an overall accuracy of 90.11% and a Kappa coefficient of 88.54%. Indeed, out of a total of 2437 pixels, 2196 pixels were correctly classified. As for confusions, 19.41% of perennial crops were confused with forests, while 9.98% of food crops/fallow were confused with built-up areas/bare ground (Table 3).

Table 3 : Confusion matrix of the TM 1986 image classification.

CLASSES	Building/bare ground	Perennial crop	Food crop/fallow	Forest	Water body
Building/bare ground	93,64	0	9,98	0	0
Perennial crop	0	87,26	0	19,41	0
Food crop/fallow	6,36	0	90,02	0	8,83
Forest	0	12,74	0	80,59	0
Water body	0	0	0	0	91,17
TOTAL	100	100	100	100	100

Overall Accuracy (Overall Accuracy = 2196/2437) = 90.11%; Kappa Coefficient = 0.8854 or 88.54

- **Confusion matrix analysis of the ETM+ image classification, 2000**

The supervised classification of the 2000 ETM+ image gives an overall accuracy of 94.58% with a Kappa coefficient of 91.34%. Out of a total of 2,437 pixels, only 2,305 pixels were well classified. The confusions that appear in the matrix show that 14.8% of the perennial crops were confused with the forest class and 8.22% of the forests were confused with food crops/fallow (Table 4). Confusions are also perceived between the classes Building/Bare soil and Food crops/Fallow for 6.84%.

Table 4 : Confusion matrix of the ETM+ 2000 images classification.

CLASSES	Building/bare ground	Perennial crop	Food crop/fallow	Forest	Water body
Building/bare ground	97,13	0	6,84	0	10,68
Perennial crop	0	85,20	0	0	0
Food crop/fallow	2,87	0	93,16	8,22	0
Forest	0	14,80	0	91,78	0
Water body	0	0	0	0	89,32
TOTAL	100	100	100	100	100

Overall Accuracy (Overall Accuracy = 2305/2437) = 94.58%; Kappa Coefficient = 0.9194 or 91.34%.

- **Confusion matrix analysis of the OLI-8 image classification, 2021**

The results of the Confusion Matrix analysis of the supervised classification of the OLI-8 image in 2021 do not differ much from those of 1987 and 2000. Out of a total of 2437 pixels, 2271 pixels were well classified providing an overall accuracy of 93.18% and a Kappa coefficient of 89.45%. The most important confusion is perceived between the food crop/fallow and forest classes (Table 5). Indeed, 18.47% of food crops/fallow were confused with forests. In addition, significant confusion was recorded between the perennial crop and food/fallow crop classes at 11.76%, and between the forest and perennial crop classes at 13.92%.

Table 5 : Confusion matrix of the OLI-8 image classification, 2021.

CLASSES	Building/bare ground	Perennial crop	Food crop/fallow	Forest	Water body
Building/bare ground	94,51	0	0	0	0
Perennial crop	0	88,24	0	13,92	0
Food crop/fallow	0	11,76	81,53	0	0
Forest	0	0	18,47	86,08	5,09
Water body	5,49	0	0	0	96,91
TOTAL	100	100	100	100	100

Overall Accuracy (Overall Accuracy = 2271/2437) = 93.18% ; Kappa Coefficient = 0.8945 or 89.45

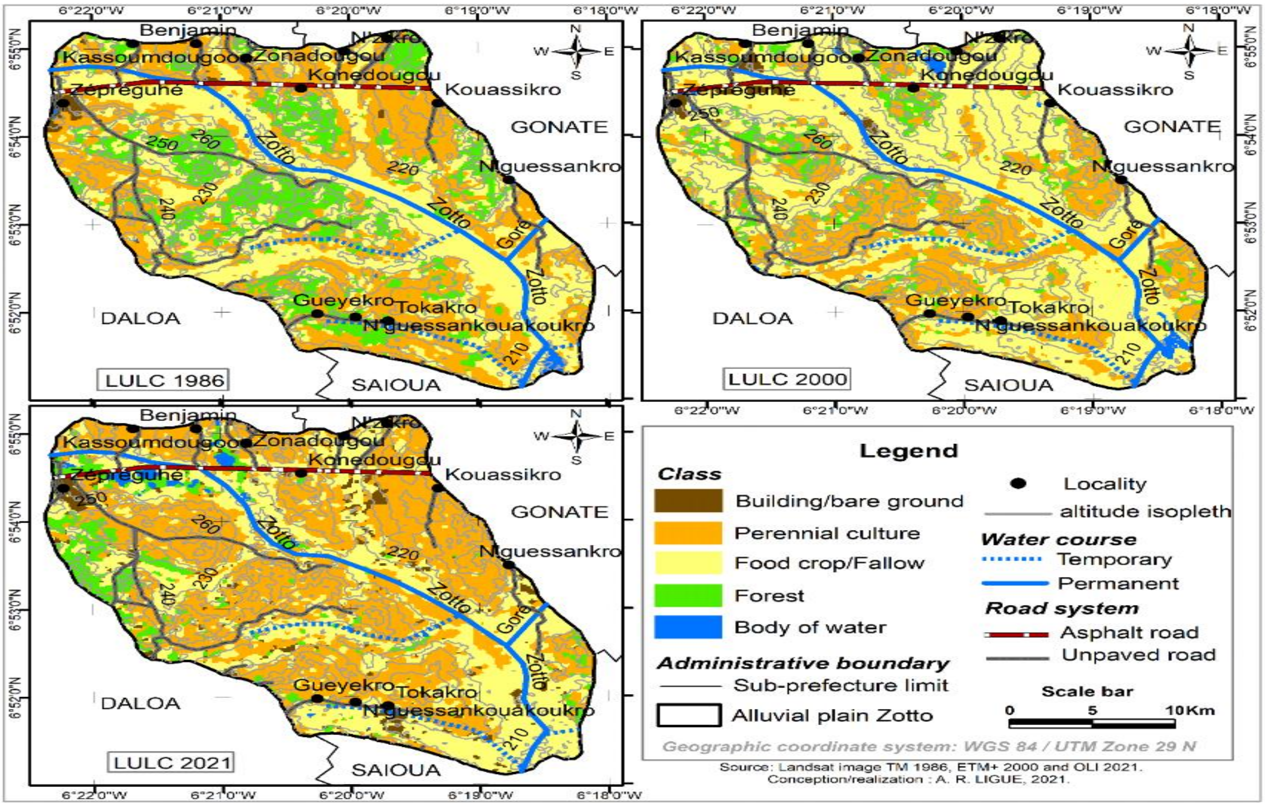
3.2. Uncontrolled land use on the floodplain in 1986, 2000 and 2021

3.2.1. Evaluation of human impact according to the terrain's toposequence in 1986, 2000 and 2021

The descriptive analysis of the land use maps provides a better understanding of the farmers' use of the land on the alluvial plain. This land mapping shows the different land use units grouped into two main features, namely natural and humanised space. The natural space is made up of forest and water areas, while the humanised space is made up of buildings/bare land, perennial crops and food crops/fallow crops (Figure 2).

Furthermore, the topography of the environment has a considerable influence on the use of the land on the plain. Indeed, perennial crops and forests are more present on the high slopes, while food crops/fallow crops are developed on the low slopes (Figure 2). This spatial distribution of crops is clearly linked to the nutritional characteristics of the plants, which vary from one species to another. Perennial crops favour medium-high slope environments with ferrallitic soils. Food crops, on the other hand, thrive on low slope areas with hydromorphic soils.

Figure 2: Land use map of the Zotto floodplain in 1986, 2000 and 2021



3.2.2. Statistical analysis of land use units in the plain in 1986, 2000 and 2021

Statistical analysis of the results of the image classification shows variations in surface area over time and space in the study area (Table 6). Overall, in 1986, the natural area covered a total surface of 739 hectares, i.e. 18%, compared with 3,131 hectares (i.e. 82%) of the humanised area. In 2000, the natural area covered only 349 hectares (or 9%) of the mapped area compared with 3521 hectares (or 91%) of the humanised area. In 2021, the natural area will occupy 300 hectares, i.e. 8% of the plain, compared with 3570 hectares of humanised area, i.e. 92%. In part, the observation shows that over the years, the natural areas of the plain are shrinking to the detriment of the humanised areas. Demographic growth, the topography of the area and the fertility of the land are the key factors responsible for these changes.

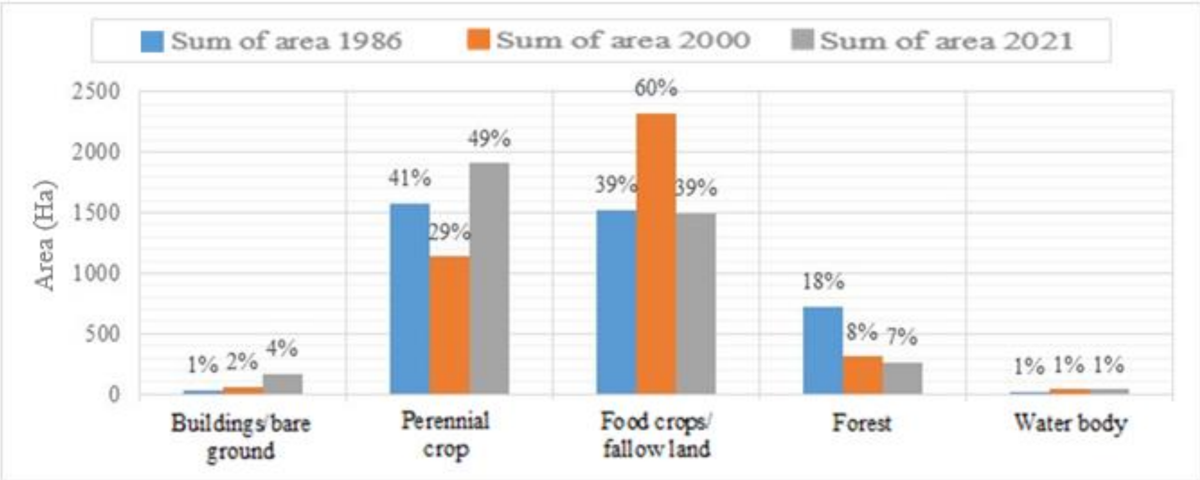
Table 6: Land use statistics in 1986, 2000 and 2021.

	Classes	1986		2000		2021	
		Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)
Humanised space	Buildings/bare ground	37	1	57	2	165	4
	Perennial crop	1575	42	1138	29	1911	49
	Food crops / fallow land	1519	39	2326	60	1494	39
Natural area	Forest	722	17	310	8	262	7
	Water body	17	1	39	1	38	1
Total		3 870	100	3 870	100	3 870	100

Source: Land use map 1986, 2000 and 2021.

The graph below (Figure 3) summarises the evolutionary trend of land use areas over the intervals of the defined study periods. The detailed statistical analysis of the graph shows that in 1986, perennial crops and food crops/fallow have the largest portions of the mapped area with 41% and 39% respectively, compared to 18% of forests and 1% of built-up areas/bare land and water. In addition, in 2000 changes are seen at the class level. Thus, food crops/fallow crops have a remarkable development with a proportion of 60% of the space, against 29% of perennial crops, 8% of forest spaces, 2% of built-up areas/bare ground and 1% of water areas. In 2021, perennial crops will have the largest surface area, covering 49% of the plain, compared with 39% for food crops/fallow crops, 7% for forests, 4% for built-up areas/bare ground and 1% for water bodies.

Figure 3: Spatial and temporal evolution of land use unit areas from 1986 to 2021.



Source: Land use map 1986, 2000 and 2021.

In order to better understand the changes during the period 1986 to 2021, the rates of change of the different land use units as well as the overall rates calculated in percentages are summarised in Table 7.

Table 7: Statistical results of land use rates from 1986 to 2021.

	Area (Ha)			Annual Tc (%)			Overall Tx (%)		
Classes	1986	2000	2021	1986 à 2000	2000 à 2021	1986 à 2021	1986 à 2000	2000 à 2021	1986 à 2021
Buildings/bare ground	37	57	165	3,1	5,2	4,4	+54,1	+189,5	+345,9
Perennial crop	1575	1138	1911	-2,3	2,5	0,5	-27,7	+67,9	21,3
Food crop / fallow	1519	2326	1494	3,1	-2,1	-0,1	+53,1	-35,8	-1,6
Forest	722	310	262	-5,9	-0,8	-2,8	-57,1	-15,5	-63,7
Water body	17	39	38	6,1	-0,1	2,3	+129,4	-2,6	+123,5
Total	3 870	3 870	3 870						

Source: Land use map 1986, 2000, and 2021.

From 1986 to 2000, there was an increase in the water body, buildings/bare land and food crop/fallow classes of 6.1%, 3.1% and 3.1% respectively. Regressions are seen in the Forest and Perennial Crop classes, respectively -5.9% and -2.3%. Over the same period, there was also an increase in the classes Buildings/bare soil, Water body and Perennial crop of 4.4%, 2.3% and 0.5%. In addition, there is a regression in the Forest and Food crop/fallow classes of around -2.8% and -0.1% respectively. From 2000 to 2021, the built-up/unprotected land and perennial crop classes show an increase of 5.2% and 2.5% respectively, as do the food crop/fallow, forest and water classes, which show an increase of -2.1%, -0.8% and -0.1% respectively. The built-up areas/bare soil increased by more than 345.9% between 1986 and 2021, while the food crops/fallow land class decreased by 1.6% in the alluvial plain.

3.3. Detection of land use changes in 1986, 2000 and 2021 in the plain.

The mapping of the cross-referenced land-use maps provides a better understanding of the different areas that have remained stable and those that have undergone changes. Thus, out of a total of 3,870 hectares, 1,369 hectares (i.e. 35%) remained stable, compared with 2,501 hectares (i.e. 65%) which were transformed between 1986 and 2000 (Table 8).

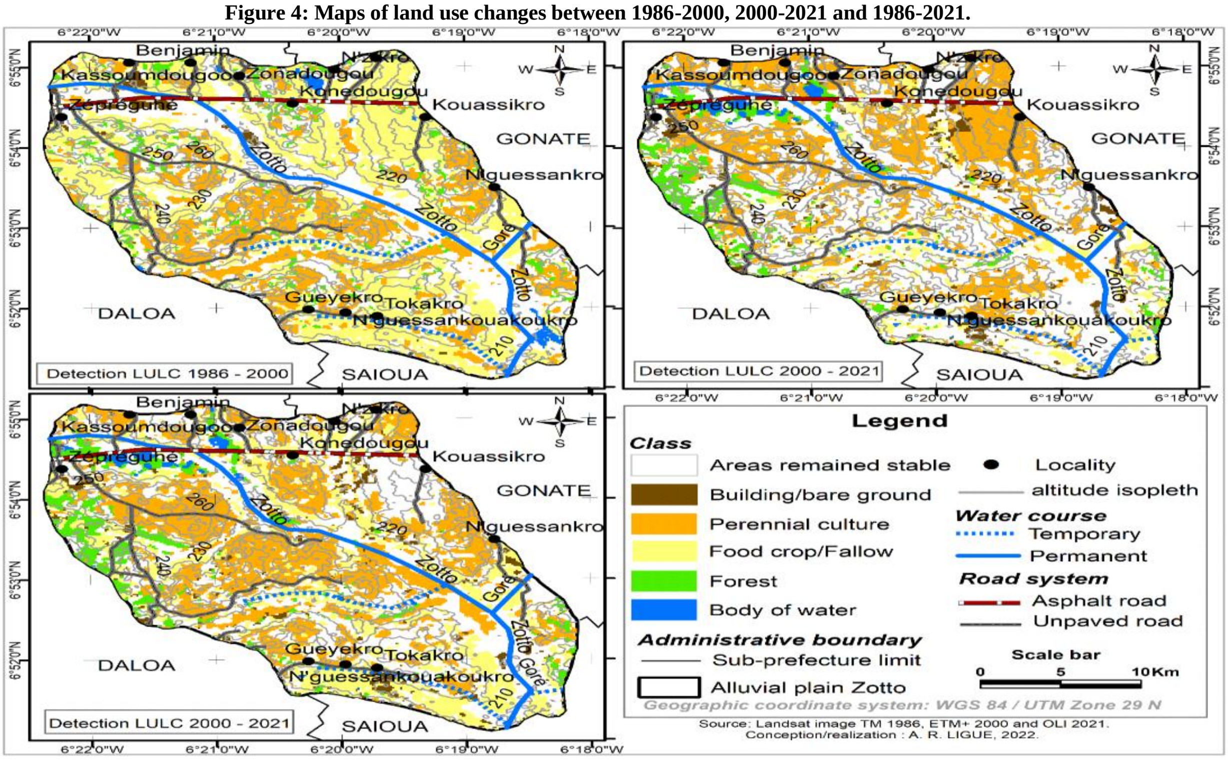
Between 2000 and 2021, 52% of the area (i.e. 2020 hectares) remained stable compared with 42% (i.e. 1 850 hectares) of the total area. Similarly, between 1986 and 2021, 39% (or 1,516 hectares) of the area remained stable compared with 51% (or 2,354 hectares) of the unstable area. The figure below shows the maps resulting from the spatial transformations following the cross-referencing of the land-use maps of the Zotto river alluvial plain in Zépréguhé.

Table 8: Land use class conversion statistics from 1986 to 2021

	Classes	1986 à 2000		2000 à 2021		1986 à 2021	
		Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)
Instability	Buildings/bare ground	21	1	36	1	19	1
	Perennial crop	1 275	33	333	9	815	21
	Food crops / fallow land	625	16	1 157	30	813	21
	Forest	564	14	285	7	690	17
	Water body	16	1	39	1	17	1
Stability	Areas remained stable	1 369	35	2020	52	1516	39
Total		3 870	100	3 870	100	3 870	100

Source: Cross-referencing of land use maps 1986-2000, 2000-2021 and 1986-2021.

Figure 4: Maps of land use changes between 1986-2000, 2000-2021 and 1986-2021.



3.3.1. Land use dynamics between 1986 and 2000.

The analysis of the transition matrices generated by crossing the land use maps highlights the different spatial transformations that occurred between 1986 and 2000, 2000 and 2021, and 1986 and 2021 in the Zotto river alluvial plain. These spatial transformations can be summarised as areas that have remained stable and those that have changed over time. Thus, from 1986 to 2000, the class that remained the most stable was food crops/fallow with 38%, compared to 27% for the built-up area/bare ground and forest classes, 26% for perennial crops and 7% for the water body (Table 8). Moreover, significant instabilities are perceived between certain land use units. Indeed, 49% of perennial crops have been transformed into food crops/fallow, 31% are replaced by buildings/bare land and 42% have evolved towards the forest class. Similarly, food crops/fallow crops have been transformed into other land use types. Thus, they lost part of their area, 40% of which was replaced by buildings/bare ground, 44% was occupied by perennial crops and 43% was flooded (water body). In the same period, 31% of the forest has been reconstituted at the expense of food crops/fallow. In addition, part of the forest has been replaced by other land uses. Thus, 30% of the forest was converted into perennial crops, while 11% was converted into food/fallow crops.

Table 8: Transition matrix of spatial changes between 1986 and 2000

		2000					
	Classes	**Buildings/bare ground**	**Perennial crop**	**Food crop/fallow**	**Forest**	**Plan Water**	**Total (Ha)**
1986	Buildings/bare ground	16 (27%)	0 (0%)	19 (1%)	0 (0%)	1 (3%)	36
	Perennial crop	18 (31%)	301 (26%)	1141 (49%)	127 (42%)	17 (45%)	1604
	Food crop/fallow	23 (40%)	506 (44%)	893 (38%)	95 (31%)	17 (43%)	1534
	Forest	1 (1%)	338 (30%)	255 (11%)	83 (27%)	1 (2%)	678
	Water body	1 (1%)	0 (0%)	14 (1%)	0 (0%)	3 (7%)	18
	Total (Ha)	59 (100%)	1145 (100%)	2322 (100%)	305 (100%)	39 (100%)	3870

Source: Cross-referencing of land use maps 1986 and 2000.

3.3.2. Land use dynamics between 2000 and 2021.

Between 2000 and 2021, the class with the greatest stability is the food crop/fallow class with a proportion of 78%, followed by perennial crops (41%), buildings/bare ground (11%) and forests (9%). The transformations that occurred in the plain are multiple, the most noticeable of which were recorded between the food crop/fallow and water body classes (Table n°9). Indeed, 77% of the food crops/fallow crops have been replaced by water bodies. This is due to the waterlogging of the plain during a certain period of the year. Also, 44% of the same crop has given way to perennial crops. Similarly, 71% of food crops/fallow crops were transformed into built-up areas/bare land. In the same period, 12% of the forest shrank in favour of perennial crops and 3% shrank in favour of food crops/fallow.

Table 9: Transition matrix of the classification estimate between 2000 and 2021

		2021					
	Classes	**Buildings/bare ground**	**Perennial crop**	**Food crop/fallow**	**Forest**	**Water body**	**Total (Ha)**
2000	Buildings/bare ground	17 (11%)	3 (1%)	26 (2%)	3 (1,5%)	8 (20%)	57
	Perennial crop	25 (15%)	808 (41%)	225 (15%)	85 (32%)	1 (3%)	1144
	Food crop/fallow	117 (71%)	859 (44%)	1168 (78%)	152 (57%)	29 (77%)	2325
	Forest	4 (2%)	232 (12%)	44 (3%)	25 (9%)	0 (0%)	305
	Water body	2 (1%)	7 (2%)	29 (2%)	1 (0,5%)	0 (0%)	39
	Total (Ha)	165 (100%)	1909 (100%)	1492 (100%)	266 (100%)	38 (100%)	3870

Source: Cross-referencing of land use maps 2000 and 2001.

3.3.3. Land use dynamics between 1986 and 2021

Analysis of the transition matrix statistics between 1986 and 2021 shows that the most stable class is the food crop/fallow class with a proportion of 47%, compared to 40%, 13%, 11% and 2% respectively for the perennial crop, forest, built-up area/bare soil and water body classes (Table 10). However, there are several mutations between the classes. Thus, nearly 49% of the areas dedicated to perennial crops were transformed into buildings/bare ground and 42% into food crops/fallow. In the same period, 41% of perennial crops are converted into forest.

Table 10: Transition matrix of the classification estimate between 1986 and 2021

		2021					
	Classes	**Buildings/bare ground**	**Perennial crop**	**Food crop/fallow**	**Forest**	**Plan Water**	**Total (Ha)**
1986	Buildings/bare ground	18 (11%)	4 (1%)	14 (1%)	1 (1%)	0 (0%)	37
	Perennial crop	82 (49%)	756 (40%)	620 (42%)	111 (41%)	-	1574
	Food crop/fallow	51 (31%)	612 (32%)	704 (47%)	120 (45%)	32 (85%)	1519
	Forest	13 (8%)	538 (28%)	138 (9%)	33 (13%)	0 (0%)	722
	Water body	1 (1%)	0 (0%)	16 (1%)	0 (0%)	1 (2%)	18
	Total (Ha)	165 (100%)	1910 (100%)	1492 (100%)	265 (100%)	38 (100)	3870

Source: Cross-referencing of land use maps 1986 and 2001.

The area under food crops/fallow crops is shrinking. Thus, 31% of this crop has been converted to built-up areas/bare ground. 32% have been transformed into perennial crops and 45% have been converted into forest. Forests have also been reduced, losing 8% of their area to built-up areas/bare ground. 28% of this forest has been replaced by perennial crops, while 9% is occupied by food crops/fallow.

3.4. Distribution of key players in the floodplain

The dynamics of the Zotto alluvial plain are driven by different actors, both Ivorians and non-Ivorians, who come from different backgrounds. Thus, 66% of the farmers exploiting the alluvial plain are allochthones (Table 11), essentially composed of Sénoufo and Baoulé. 19% of the farmers are non-natives, the majority of whom are Burkinabe and Malians. Also 15% of the actors exploiting this site are indigenous Gnaboua. These different actors develop this alluvial plain with different crops composed of perennial crops, food crops and market gardens.

Table 11: Distribution of farmers in the floodplain according to their origin

Actors	Number of farmers	Percentage (%)
Aboriginal people	12	15
Indigenous people	53	66
Allogens	15	19
Total	80	100

Source : Our fieldwork, 2019.

3.5. Access to land by farmers in the floodplain

In the Zotto alluvial plain, different modes of access to land are observed. These modes are essentially inheritance, rental and loan (Table 12). Indeed, 9% of the people surveyed obtained their farm plot by inheritance. This mode is commonly practised by indigenous people whose parents own the plots and who pass them on to their heirs as a family inheritance. In addition, 85% of the farmers in the plains rent plots of land from natives. These rentals are generally made by non-natives and natives in kind or in cash, depending on the contract. The plots are sold for a sum of 45,000 CFA francs or two 150 kg bags of rice per hectare. The acquisition of plots by loan is less widespread in the alluvial plain. It represents 6% of the people surveyed. This form of acquisition leads to conflicts between natives and non-natives. Thus, most loans are between natives and natives.

Table 12: Methods of accessing land in the floodplain

Land acquisition	Number of farmers	Percentage (%)
Legacy	7	9
Rental	68	85
Loan	5	6
Total	80	100

Source : Our fieldwork, 2019.

4. DISCUSSIONS

4.1. Evaluation of satellite image classification

The results of the classification of satellite images from the TM, ETM+ and OLI-8 sensors for the years 1986, 2000 and 2021 respectively for the study area provided overall accuracies of 91.11%, 94.58% and 93.18% respectively. Similarly, the Kappa indices gave proportions of 88.54%; 91.34% and 89.45% for the years 1986, 2000 and 2021 respectively. All these recorded indicators were considered excellent because according to R.G. Congalton (1991, 42) and J.R. Landis and G.G. Koch. (1977, p.367), they are excellent when they are above 0.80 and good when they are between 0.61 and 0.80. They are moderate when they are between 0.21 and 0.60 and poor when they are between 0.0 and 0.20. Most of these statistics obtained in the study are very close to the values of K.B. Kpangui et al. (2018, p.202) who respectively obtained overall accuracies between 82.63% and 83.80% in the Kokumbo Sub-Prefecture using Landsat images. Similarly, N. H. Dibi, E. K. N'Guessan, M. E. Wajda, K. Affian (2008, p. 24) also obtained global accuracies between 82.60% and 82.66%, respectively for the years 2003 and 1986, which are very close to those obtained by the present study even though the study area differs slightly. On the other hand, N.K.D. Edjagne, (2017, p.40) in his classification of Landsat images of three dates (1986; 2000; 2015) obtained the overall accuracies whose values are respectively 94.69%; kappa: 88.64%; 95.32%; kappa: 93.26%; 91.25%; kappa: 84.96%. These results are close to the classifications of A.G. Adou, (2015, p. 81) whose overall accuracies are 95.20% (1990) and 97.13% (2008) and those of M.R. N'go et al, (2018, p. 27) with kappa indices of 96% (1999), 95% (2006) and 93% (2009). All these results are in phase with theirs and confirm the good classification of the images in this study.

4.2. Analysis of land use dynamics

The spatial dynamics of land use in the Zépréguhé alluvial plain showed a strong anthropic pressure marked by a dominance of agricultural activities, notably the food crop/fallow class, followed by the perennial crop class. These different classes are certainly more stable in the plain, but are undergoing mutations. These results are similar to those of A.G. Adou, 2022, p19 whose study showed a dominance of perennial crops and food crops whose occupancy rate represents more than 90% of the space. For their part, K.D. Kpedenou et al (2016) and S. Zakari et al (2018) used remote sensing and GIS techniques to monitor the dynamics of land use based on diachronic mapping to show the degradation of natural plant formations and the evolution of agricultural areas and plantations. Similarly, K.B. Kpangui et al (2018, p.195) mapped and monitored the spatio-temporal evolution of cocoa cultivation in the Kokumbo sub-prefecture using Landsat images from 1990, 2002 and 2016. Their analysis shows that cocoa cultivation is taking hold to the detriment of forests and savannahs, which have lost 25% and 58% of their initial area respectively.

Other authors, such as A.G. Adou, 2015; N.K.D. Edjagne, 2017; M.R. N'go et al, 2018 used the same tools in the dynamics of land use respectively on the Alladjan coast, in the Affema canton and in the rural commune of Koumbia in Burkina Faso in their study. These studies also showed a dominance of agricultural activities and a regression of forest cover due to anthropogenic factors. For B. Tankoano, (2012, p.44), the regression of woody cover was attributable to the combined effect of rainfall variability and anthropogenic pressures. This claim is confirmed by T.

B.A. Zamblé (2013, p.124) who combined agricultural and population statistics with Landsat and Spot 5 imagery to understand the correlation between vegetation evolution, climate dynamics and anthropogenic pressures.

Knowledge of the characteristics of the sector's ecosystems and their evolution over time and space is essential for land use planning and sustainable management of these resources (B.T. Agbanou et al, 2018, p. 23). The strong human hold, to which are linked different land use modalities, explains to a large extent the great variability of environmental degradation phenomena, which has as a corollary the acceleration and diversification of erosive phenomena (Z. Amhani, et al, 2016, p. 293). It occurs when soils are fragile, the vegetation cover is reduced and the climate is particularly unforgiving (H. Sawadogo et al 2008, p. 60). Indeed, the strong anthropic pressure exerted on upland areas in zones conducive to the development of cash crops has led to a decrease in soil fertility and a significant drop in yields (S. Worou, 2007, p.2).

4.3. Determinants of the exploitation of the Zotto river floodplain

The alluvial plain of the river Zotto has undergone a transformation of its space thanks to the dynamism of several actors from different origins, the majority of whom are non-natives (66%), followed by natives (19%) and indigenous people (15%). This assertion was however invalidated by studies conducted by A.G. Adou et al, (2021, p 859) in the same plain, which show that the natives of Zépréguhé are the most involved in the production of perennial crops (120 ha or 48%) as opposed to the farmers of Fofanadougou (47 ha or 19%), Kassoundougou (43 ha or 17%) and Zanadougou (38 ha or 15%). Similarly, the results of A.G. Adou et al (2017, p 6468) corroborate the involvement of non-natives, stating that the predominant group of lowland rice farmers is the Sénoufo. Out of a total of 29 farmers interviewed, 18 are from the Sénoufo ethnic group: they represent 62.07% of the total. On the other hand, the work of Cadot et al, (1997, p 9) shows a large predominance of Sudanese non-natives in the agricultural management of the lowlands of the town of Daloa, while the natives represent only 5% of the farmers.

4.4. Negotiations between actors for access to land in the Zotto alluvial plain

The land on the alluvial plain of the Zotto river in the village of Zépréguhé belongs to various families who are originally from the village. This land, for personal or family reasons, is exploited by farmers in the form of rent, loan or inheritance. The mode of access to land by inheritance represents 9% of those surveyed. These inheritances are generally transmitted from father to son. The mode of access by inheritance is the most widespread among the indigenous people of Zépréguhé. This mode of access to land is supported by (S. Kchouk et al, 2015, p 410) who state that farmers' sons inherit small areas and mobilise the lowlands near the family farm. Indeed, the social organisation in Bete country is purely based on patriarchy. In this system, the land heritage that constitutes the forest or the lowland areas is passed from father to son (A. Diarra et al, 2020, p 254).

Land rental is mainly practised by non-natives and allochthones. This statement is confirmed by the work of (A. Diarra et al, 2020, p 254), which shows that the mode of access by renting is aimed at all migrants (allochthones and allogènes). Plots are generally rented in kind or in cash. These facts are corroborated by (Diarra et al, 2020, p 254) whose work shows that plots are rented for money or bags of rice. In the past, landowners set the rental price at 30,000 CFA francs or two bags of rice per hectare. Today it is 45,000 CFA francs per hectare, or about the price of three bags of rice.

Loans are generally a source of conflict and are rarely made in the lowlands. The 'remaining' lands, generally the lowlands, are the last spaces available for newcomers to settle (S. Kchouk et al, 2015, p 410). In sub-Saharan Africa, Chauveau et al (2006) quoted by (S. Kchouk et al, 2015, p 410) show that the land rights of migrants, perceived as 'outsiders' to the local community, are more restricted than those of natives and imply a duty to integrate into the community. The lowlands are thus a place of settlement for young rural or neo-rural people, who have a more restricted legitimacy and access to land and water resources than their elders and who are looking for new opportunities in agriculture.

CONCLUSION

The alluvial plain of the Zotto de Zépréguhé river is undergoing a major spatial transformation linked to the strong influence of agricultural activities to the detriment of the vegetation cover. These agricultural activities are essentially based on perennial crops and food crops. The mutation of this space is caused by demographic growth linked to the migration of non-native and non-indigenous populations, but also by the saturation of arable land in the plateaux. The analysis of this spatial mutation was carried out using LANDSAT TM, ETM+ and OLI images for the years 1990, 2002 and 2020. The images show the spatiotemporal evolution of the land use of the alluvial plain of the Zépréguhé river and show an increase in agricultural activities and a reduction in forest cover. In view of the consequences and environmental concerns of this deforestation, the Ivorian authorities should initiate a policy of awareness-raising in order to limit this anthropisation while preserving the environmental role of this alluvial plain of the Zotto River in Zépréguhé.

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