Identification and Characterization of Non-Cultivated Spaces by Remote Sensing in the Southern Sahelian Zone in Chad

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Abstract

In Chad, the peasant has always fought and continues to fight to maintain at an optimum level his agricultural productions, whose break-even point has been upset since the 1990s by the effects of soil erosion, following the poorly controlled agricultural practices. The identification and characterization of undeveloped or fallow areas is one way of increasing agricultural production, through the possibility of expanding the area under cultivation; which allows to increase production and guarantee food security.

The aim of this study is to test the feasibility of an agricultural statistical system using satellite remote sensing to characterize areas of agricultural preference, particularly rice. The use of SPOT data made it possible to distinguish the cultivated area (26.53%), the areas likely to be cultivated with rice (34.77%) and the non-cultivated areas (38.70%) of the selected site. . Statistical analysis of Landsat classified images from Marba indicates that the non-agricultural sectors accounted for about 62.93% in 2013 compared to 55.84% in 2000.

Key words: *Agriculture, land use, Marba, Chad.*

Résumé: Au Tchad, le paysan s'est toujours battu et continue de lutter pour maintenir à un niveau optimal ses productions agricoles, dont le seuil de rentabilité est perturbé depuis les années 1990 par les effets de l'érosion des sols, à la suite des pratiques agricoles. mal contrôlé. L'identification et la caractérisation des zones non aménagées ou en jachère constituent un moyen d'accroître la production agricole, grâce à la possibilité d'agrandir les zones cultivées; ce qui permet d'augmenter la production et de garantir la sécurité alimentaire.

Le but de cette étude est de tester la faisabilité d'un système statistique agricole utilisant la télédétection par satellite pour caractériser les zones de prédilection pour l'agriculture, en particulier le riz. L'utilisation des données SPOT a permis de distinguer la zone cultivée (26,53%), les zones susceptibles d'être cultivées en riz (34,77%) et les zones non cultivées (38,70%) du site sélectionné. L'analyse statistique des images classifiées Landsat de Marba indique que les secteurs non agricoles représentaient environ 62,93% en 2013, contre 55,84% en 2000.

Mots clés: agriculture, utilisation des sols, Marba, Tchad

Introduction

Every year in Chad, the surfaces of the main crops are roughly evaluated on simple farmer declarations at the beginning of the crop year (ANDIGUE 1999, REOUNODJI 2003, DJANGRANG 2011, DSA 2014). Because of changes during the campaign and the impossibility of lifting and census all farms, the statistics obtained are unreliable, so difficult to know precisely. At times, a two-stage random survey (villages, farms) is also carried out, where the data are collected by measuring plot-samples. The accuracy of the estimates is then available and varies from 50 to 70% depending on the means implemented.

Whatever method is used, no statistics are available on the spatial distribution of crops and the non-agricultural area, which is largely fallow. Yet characterization of land use is a good way of knowing exactly how much land is available for agricultural development.

In the Marba canton, the expansion of agricultural land abandoned pell-mell, which are however supposed to be exploited optimally for agricultural production, limits the village soil and creates an imbalance in terms of food security. However, these abandoned sectors have interesting agronomic potential that can accommodate agricultural development projects. The rehabilitation of these spaces requires first to identify the priority sectors that can be mobilized and to reference them. It is with this in mind that we have undertaken this study, based on the exploitation of LANDSAT and SPOT satellite data, to accurately characterize the rice potential of the Marba township, taking the example of the village of Méguéné. The aim is to discriminate non-agricultural areas and then stratify land cover and land use from remote sensing data. Although it is very difficult to obtain high-resolution satellite coverage of the entire rice-growing area for an optimal period to better discriminate between crops, non-cultivated areas and fallows, the study attempts to determine more precise way the surfaces of the different units of the soil.

I. Geographical setting of the study

The studied village is located in the heart of the Tandjilé rice-growing area, which allows to cross very different situations from a physiographic and human point of view. We are in a transition zone between the Sudanese and Sahelian climates, with an average annual rainfall of between 850 mm and 950 mm.

The most important rice area in the region is represented by the country Marba (13 000 ha), divided into four cantons, namely the cantons Kakraou, Tchiré, Damdou and Di. Its population is growing rapidly, growing at a rate of 5.6% per year, from 42,196 in 1993 to 93,843 in 2009 (RGPH, 1993).

The Tandjilé River, which gives its name to the region, crosses the Marba township and leads to the alluvial plain of Logone, where their waters mingle to the confluence of Eré. The Marba occupy the least exiled mounds where are located their huts and millet fields. The periphery of the hillocks is mainly devoted to rice cultivation. The areas controlled by the administration and reported by CABOT (1965) were 8 698 ha in 1953, 9 809 in 1954 and 10 756 in 1955. These stabilized at the last figures until the end of the 1980s (ONDR, 1992). From 1990 onwards, the areas cultivated with food products tend to increase. Until 1990, the cultivated area occupied between 10 and 15% of the Marba territory according to the sites (DSA, 2010).

Soils belong to the series of sandy beige soils. Their value is very unequal; the best are the clay-loam soils around the Damdou and Baktchoro Depression. The mounds which limit them carry a wooded savannah vegetation dominated by the species of Combretum, Terminalia macroptera and Ficus sp. who are comfortable with the water table near the ground. The largest and the tallest mounds sometimes retain more typically Sudanese Khaya senegalensis, Bombax costatum and Butyrospermum parkii, which are mixed with more typically Sahelian species, such as Hyphena thebaica, Acacia seyal, Tamarinus indica and Faidherbia albida.

The production system of the soil is predominantly agricultural (92% of the active population). Production is average for several reasons: flooding, low input use and low integration of livestock with agriculture. However, the terroir has the particularity of having been the subject of popularization of rice cultivation by the Experimental Sector Laï-Kélo in the 1950s, which made it possible to offset the low production due to these factors.

The village of Méguéné, with a population estimated at 2397 inhabitants in 2015, while it was 1078 inhabitants in 1993 (RGPH, 1993), is in fact one of the big villages of the canton Damdou of the sub-prefecture of Bakchoro, populated mostly from Marba. There are some Arab families who are dedicated to the sale of manufactured products. Located in the heart of the Marba country, in the Tandjilé development area, in the 1950s, the village benefited from the program of "educating the peasant for the introduction of harnessed culture on the rice fields of the three depressions. flood of Tagou, Habang and Lolora ... "CABOT (1965).

The main crop is rice, followed by red sorghum grown on small plots. The sugarcane plantation, a growing crop today, is also practiced on small plots of barely 0.15 ha.

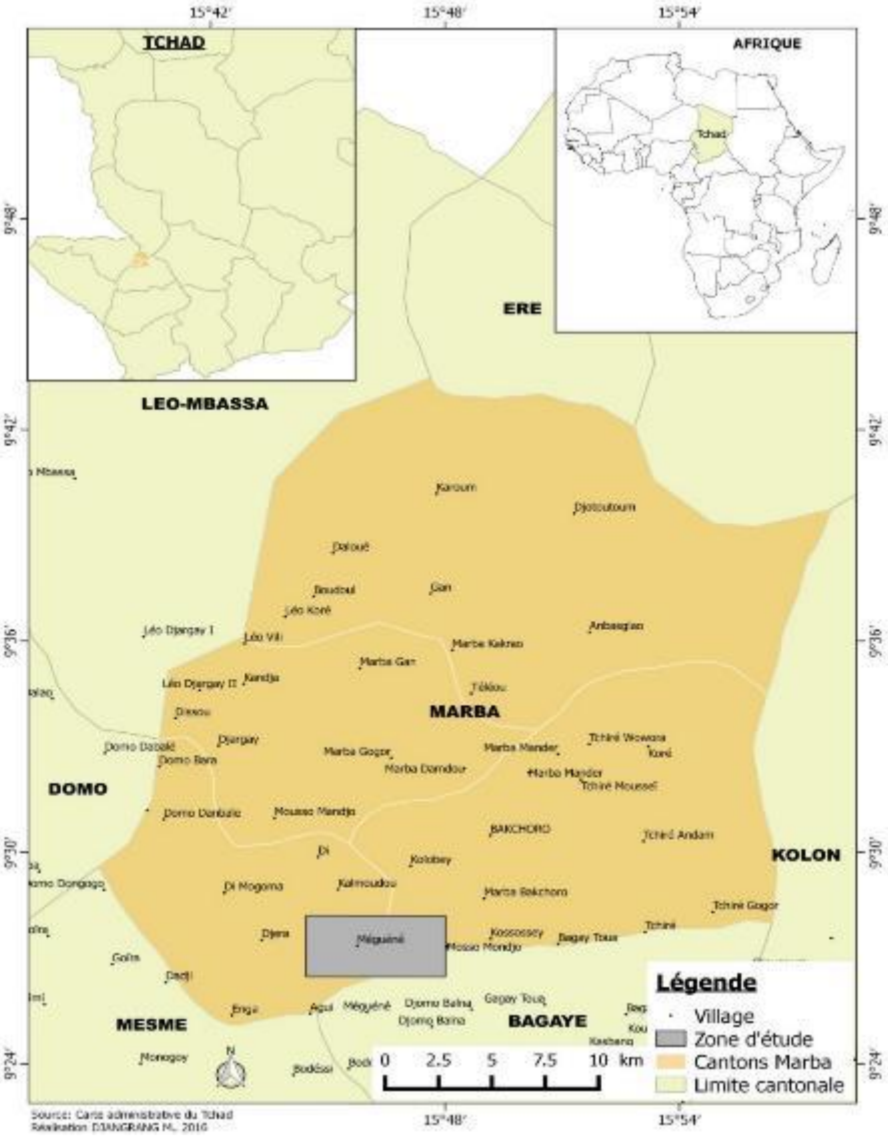

Figure 1: Marba Townships

II. The methodological approach

1. The data used

The data used concern, on the one hand, the information provided by satellites, on the other hand, those collected in a conventional way in the field. LANDSAT satellite imagery is chosen for land cover mapping because it provides a level of detail sufficient to identify land cover characteristics. The spatial resolution of the images used is 30 m. The images acquired for this exercise come from two platforms, LANDSAT 7 and LANDSAT 8.

In order to maintain coherence in the spectral response of the various plant covers, the images were all acquired during the dry period (14 February 2000 and 22 October 2013). This also allows for the greatest spectral differences between landscape features (OSZWALD et al., 2010), including the opposition between "natural" vegetation systems, whose spectral response is clearly distinguishable from "anthropogenic" systems. Which are then characterized at this time by a virtual absence of vegetation.

Due to the small size of plots (most often between 0.5 and 2 ha) and the need to distinguish crops at the local scale, SPOT imagery data were used. The use of the SPOT image naturally necessitated what is called "field truths", in order to choose the test areas on which the treatments are initialized in order to make an objective and precise evaluation of the results of these treatments.

The field reconnaissance took place one year after the date of acquisition of the image, from 18 to 28 September 2015, during which time the vegetation is in full growth phase. Ground observations were made using a stratified sampling design (LONG, 1974). It was therefore based on all the existing information (topographic maps and agricultural surveys of the Ministry of Agriculture) as well as an ecological zoning a priori of the region, based on the visual interpretation of colored compositions (HRV data from SPOT 2014) and supervised classifications made from the same data.

The methodology adopted takes into account the specificities of the satellite data used as well as the expected products. It combines the use of two techniques: the unsupervised classification for Landsat data and the supervised classification for SPOT.

2. Classification of images

The classification chosen is the so-called supervised (or "directed classification") classification for the SPOT image. Based on our knowledge of the terrain and the spectral signature, we defined for each pixel of our image its class of membership. The algorithm used is that of the maximum likelihood which is based on the rule of Bayes allowing to calculate for each pixel its probability of belonging to one class rather than another. The pixel is assigned to the class with the highest probability of belonging.

The process followed is summarized in three stages:

- Visual interpretation of satellite images based on both the characteristics of the land-use classes and our knowledge of the terrain;
- Selection of a number of training zones for the desired classes;
- The evaluation of the reliability of our classification and the control of the result obtained thanks to the confusion matrix.

In this study, six classes of land use were defined (Table 1):

Table 1: Land cover classes

Classes	Description
Shrub savanna	Spaces moderately covered.
Grassy savannah	The sparsely populated spaces
Bare ground	Areas where vegetation cover is absent, this class also contains the

	plowed land of the excavated areas.
Floodplain	This class corresponds to areas still wet during the shooting period.
Open water	This class consists of: Pond - Tired - River
Champs	This category includes cultivated areas with low vegetation cover when satellite images are taken and plowed surfaces. Low-lying rainfed rice fields are either classified as flood plain or grassy savannah.

For LANDSAT images, the unsupervised method has been applied. Themes were also limited to six classes.

II. Results and discussion

1. State of land use in 2000 and 2013

In 2000 (Fig. 1), land use is dominated by areas of spontaneous vegetation, namely grassland and shrub savannah, of 26,566 hectares, or 26.05% of the total area. Marba township. The cultivated areas occupy nearly 45,028 hectares, or 44.15% of the territory. The bare soil and the plain cover respectively 17.17% and 9.52%. The largest proportion of the bare soil class is related to the difficulty of discriminating very precisely the bare soil of the cultivated area at this time of the year. As in 2000, the cultivated area occupies the first place with 41 881 hectares in front of the savannas (34 749ha) in 2013 (Figure 3), the bare soil covers 22.74% of the mapped area.

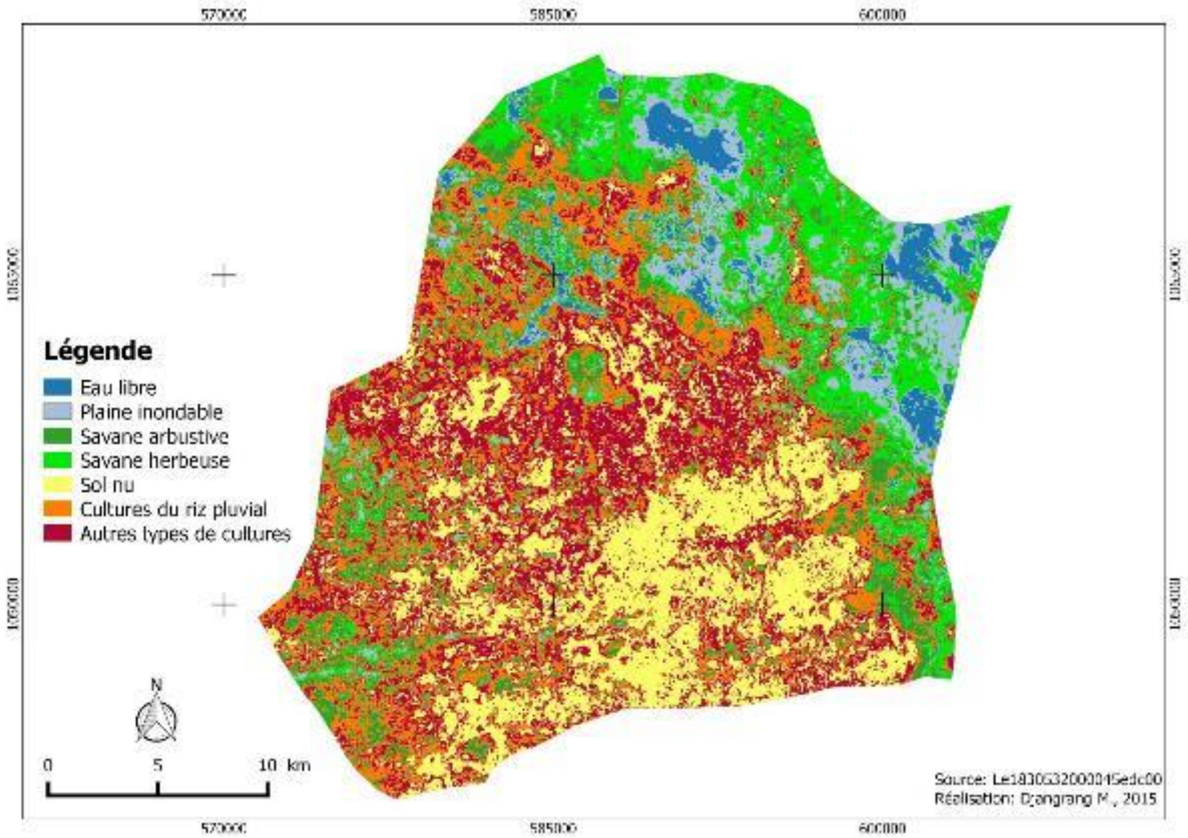

Figure 2: State of land use in 2000

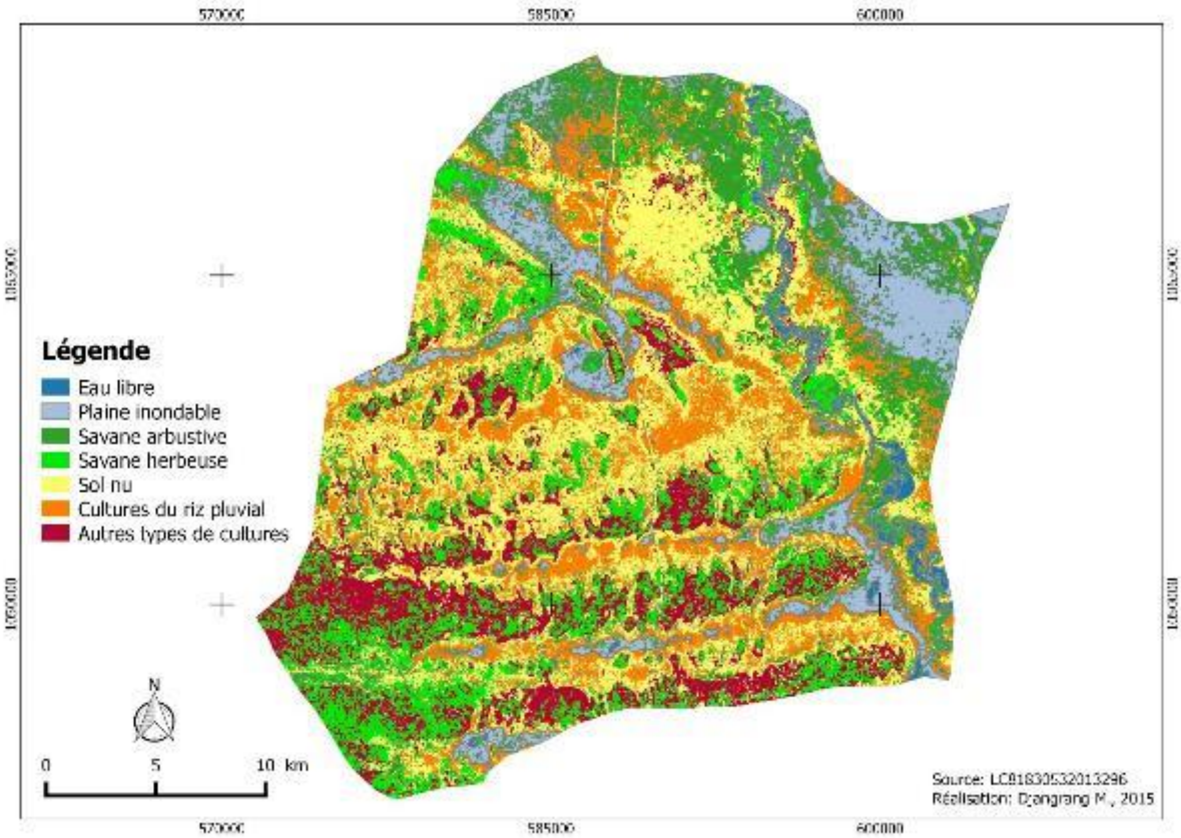

Figure 3: State of land use in 2013

The soil classification obtained from the 2000 image, compared to that of 2013, shows a remarkable change in land use at the cantonal scale. The comparative analysis of the two layers shows essentially 44.16% of agricultural land in 2000 and 37.07% in 2013.

Table 2: Variation in land use area between 2000 and 2013

Units of land occupation	2000		2013		Difference 2013 and 2000	
	ha	%	ha	%	ha	%
Shrub savanna	12708,18	12,46	16386,93	14,50	3678,75	2,04
Grassy savannah	13857,57	13,59	18362,16	16,25	4504,59	2,66
Bare ground	17505,9	17,17	25695	22,74	8189,10	5,57
Floodplain	9706,32	9,52	23644,44	20,93	13938,12	11,41
Open water	3160,62	3,10	1630,98	1,44	-1529,64	-1,66

Rainfed rice fields	16379,73	16,06	27263,07	24,13	10883,34	8,07
Other types of fields	28648,08	28,10	14617,89	12,94	-14030,19	-15,16
Total	**101966,4**	**100,00**	**112982,58**	**100,00**	**11016,18**	**0,00**

Source: *Landsat scene analysis acquired in 2000 and 2013*

Over the entire period considered, from 2000 to 2013, the overall analysis of changes at cantonal level shows that the distribution of the main land-use classes has evolved considerably in space and time. On the 2013 map, the main cereal zones are concentrated along the plains. Rice fields are dominant in the East and in the North Center. Areas dominated by meadows are located in the far north, areas that are primarily for cattle rearing. When considering all cropland, no major changes have occurred in the last 13 years. However, a more detailed analysis shows that the areas occupied by rice cultivation have increased and that changes have marked the cultivated land, the most important change being agricultural migration to the plains.

In areas dominated by grassland savannah, cereal areas appear sparsely on the 2000 map, but concentrated in 2013. On the scale of the study period, there is an intensification of production systems. The reduction of savannah areas in favor of cereal areas highlights changes related to political and economic factors. Before 2000, the State promoted the intensification of agriculture which resulted in the increase of cereal crops, in particular rice. Because the areas of the upland areas are unprofitable, farmers have moved more and more towards the plains. From 2010, the extension of tractors seems to considerably increase the cultivated agricultural areas.

2. Decrease of cereal crop land other than rice

At the regional level, cereal areas other than rice cultivation declined over the entire period from 2000 to 2013, from 28.10% to 12.94%. This reduction is confirmed by the National Office for Rural Development (ONDR), which has since 2016 become the National Agency for Rural Development (ANADER).

The reduction of cultivated areas is mainly in favor of shrub savanna, which characterizes fallow land. At the regional scale, shrubby savannas increase by 3.79% over the entire period, ranging from 12.46% to 16.25%, which indicates the regeneration of cropland, hence the availability agricultural land. The central and southeastern regions of Marba are the most affected.

In terms of space, intercrops are clearly decreasing in all the large, intensively cultivated areas of Bakchoro. The mapping of land use in 2013 gives a positive assessment, no plot island near the plains having remained in bare soil. However, the same map shows large, almost permanent islands of bare or poorly covered soils in the extreme north and east of the Marba country. Thus, it is within the sectors cultivated in rice and, especially at the beginning of the period 2000 to 2013 that the soils situated slightly below the mounds have remained constantly naked. In addition, no plot of sorghum, millet and sesame was regularly covered.

Only one very intensive sector, centered on Bakchoro, shows a very important evolution, with a better ground cover in rice cultivation, the main cash crop in the Marba country.

This cartographic analysis makes it possible to highlight the sectors presenting an environmental risk: the West and the South of the Marba country. At the local scale, the agricultural extension is particularly noticeable, like the terroir of Méguéné.

3. Discrimination from the non-agricultural domain

Discrimination of cultivated plots in fact conditions the rest of the study. We were unable to establish a relationship between the cultivated plots and the nature of the crops for this period of acquisition of the SPOT scene. The reason is quite simple: the field work took place one year after the date of acquisition of the images. The discrimination is only radiometric (LAINE, 1991). Analysis of the SPOT XS scene acquired in late October led to the following conclusions:

- cash crops, in particular sesame and beans, can not be distinguished from each other because each of these crops has a strong inter-plot heterogeneity;
- many elements of the non-cultivated domain then have radiometric behavior close to that of food crops (rice, maize, sorghum, etc.) arriving at the end of ripening.

To delineate the cultivated area, we used the SPOT XS and P data. The method was used by CANCES (1991) to isolate the plots grown in the cotton zone of Burkina Faso. The results obtained by classification are unequal because some uncultivated bare soil, in particular clay-sandy derived from the Continental Terminal with an old shallow ferruginous cuirass, proved to be identical to those of the fields already harvested. This ultimately results in an overestimation of the agricultural domain reaching in places 1.26% (Table 2).

The use of panchromatic data has improved the delimitation of these sown areas. In this image where the histogram is bimodal, TOLLET (1992) proposes the following approach that we adopted:

- thresholding in 2 regions;
- homogenization of regions;
- Obtaining contours by subtracting the image from the same image dilated by mathematical morphology.

This method has made it possible to quickly obtain a fairly precise outline of the cultivated area, for example the terroir of Méguéné (Figure 4). However, some plots which are visually identifiable by virtue of their contrast with their immediate environment and in fact have radiometry identical to that of certain components of herbaceous vegetation, could not be capitalized in the cultivated area. We therefore proceeded to a development of the method in the sectors of the image with high inter-parcel variability (East of the map) by adopting the methods of segmentation by fusion, as proposed by BLEUZEN (1989). In order to keep only the variations due to the region limits, the use of smoothing filters respecting the contours has made it possible to improve the results where the cultivated plots are represented in the figure below in dark pink to clear; bare soils in blue tending towards black and vegetation in green.

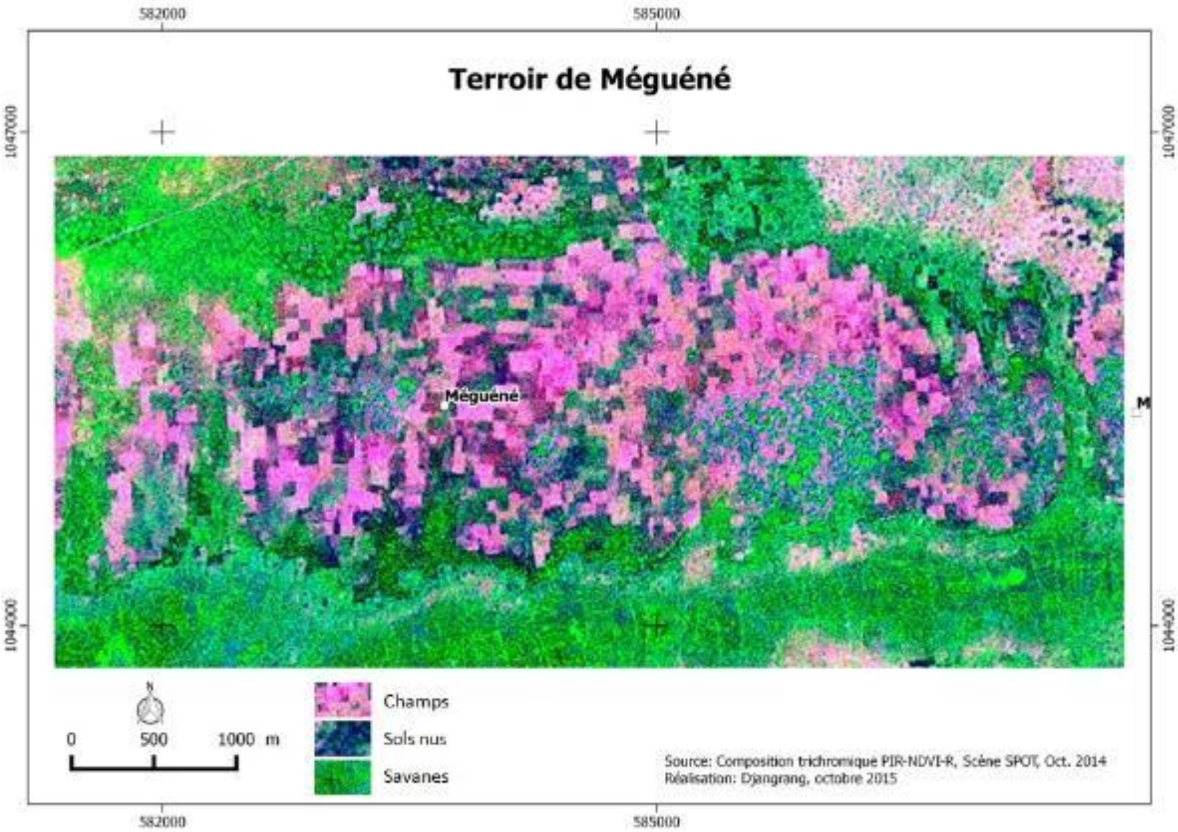

Figure 4. Cultivated areas of the Meguéné terroir in 2014

By placing itself within the cultivated area previously delimited in the Méguéné terroir, the XS image of the end of the rainy season made it possible to proceed to the evaluation of non-cultivated plots by numerical means (directed classification). Several training subclasses, because of the high interspecies variability of food crops, have been grouped together. The numerical evaluation of the SPOT scene on the Méguéné terroir provided an estimate of the distribution of the landscape units with an overall accuracy of 97.22%.

Table 3: confusion matrix at the first stage

Class	**Champ**	**ParcNC**	**SavArb**	**SavHerb**	**Total**
Champ	97.92	1.26	0.00	0.00	19.73
ParcNC	2.08	97.47	0.47	0.56	23.51
SavArb	0.00	1.26	99.29	2.23	25.75
SavHerb	0.00	0.00	0.24	97.22	31.01
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Legend: ParkNC = Uncropped plots; SavArb = Shrub savanna; SavHerb = Grassy Savannah. Legend: ParkNC = Uncropped plots; SavArb = Shrub savanna; SavHerb = Grassy Savannah.

However, given the high heterozygosity of the crops, there was considerable confusion (Table 3) between the cultivated area and non-cultivated plots (2.08%) and low confusion between non-plots. cultivated, field and grassy savannah (1.26%). The origin of the confusion is attributable to the uncultivated plots still very green at the end of the rainy season.

On the classified image, the non-agricultural sectors are not clearly distinguishable. We had to refine the result of the classification thanks to the post-classification and regularization treatments which according to DUCROT (2005), "corresponds to an adjustment of the classified image to the plots". By this method, the isolated pixels are thus eliminated by assigning them to the majority class surrounding it. The accuracy rate of the classification increased from 97.22 to 99.77% (Table 4).

Table 4: confusion matrix after regularization

Class	Champ	ParcNC	SavArb	SavHerb	Total
Champ	100.00	0.25	0.00	0.00	19.91
ParcNC	0.00	99.75	0.00	0.19	23.39
SavArb	0.00	0.00	100.00	0.56	25.10
SavHerb	0.00	0.00	0.00	99.26	31.60
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

The segmentation threshold is chosen according to the application. The principle is always that of the majority filter, but the window on which the filter is applied is the region of the segmented image (the uncultivated parcels), the pixels of the region are replaced by the majority class. The selected segmentation threshold is the one that is closest to the non-agricultural land parcel. On this principle, we have obtained the map below (Fig. 5).

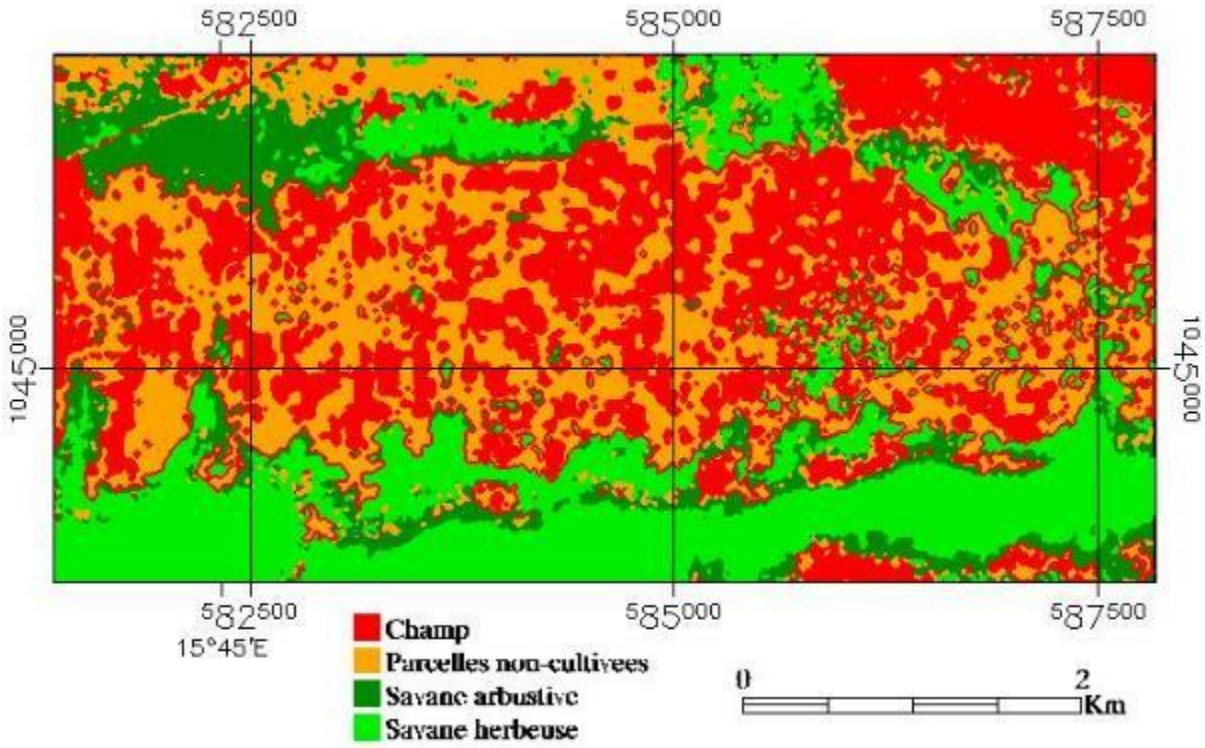

Figure 5: nonagricultural domain mapping by classification and segmentation in 2014

Over the entire mapped area, the non-agricultural domain appears clearly (in orange); the seeded plots are represented here by the red color, the vegetation is in dark green to light green. The entire non-cultivated area is estimated at about 708 ha, or 34.77% of the mapped area. These are plots that have been at least once farmed, and then abandoned for a very long time. If we add to these plots, the space occupied by the grassy savanna which lends itself very strongly to the cultivation of rice, the non-agricultural space will be 1212 ha (Table 5). This stretch of uncultivated land can be well developed by rural actors through agricultural development projects.

Table 5. Ventilation of land use

Landscape units	**Surface in ha**	**%**
Field	535,53	26,53
Non-cultived plots	701,78	34,77
Shrub savannah	262,04	12,98
Grassy savannah	510,36	25,28

Source: SPOT Scene Classification, October 2014

Conclusion

The analysis of the land use maps, the result of the supervised and unsupervised classification of Landsat and SPOT images, has shown that the Marba township has been marked over the last ten years by a remarkable evolution of its agrarian landscape. The most tangible changes relate to the area of crops, which has spread strongly to the plains as a result of population growth. The consequences of such an evolution have resulted in the conquest of new spaces for rice cultivation, which leads to the decline of the shrub savannah.

At the scale of the soil of Méguéné, it has been highlighted that the potential of rice production exists in terms of land availability. In fact, uncultivated areas exist towards the lowlands and could be the subject of agricultural development within the framework of the projects. However, the real problem lies in the mastery of the water because of the variable flood that can lead to the destruction or good production of rice. At this level, knowledge of the climatic parameters is an essential element to take into account if one wants to estimate the non-agricultural domains precisely.

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