Agricultural Zones Change and Availability of Food Crops on the Plateau of Allada in South-Benin

Naboua KOUHOUNDJI, Luc O. SINTONDJI, Vincent J. MAMA, Expédit W. VISSIN, Georges A. AGBAHUNGBA

Abstract— The goal of this survey is to understand the evolutions undergone by the agricultural zones of the plateau of Allada between 2002 and 2014 in the perspective of a sustainable agriculture. This geomorphologic space of Benin, with a surface of 2,037 km^2, welcome a population of 717,813 inhabitants in 2013, either a density of 352 habitants/km^2. The agricultural production is essentially rainfed. It is taking more and more space. Then, it is convenient to analyze the rhythm of extension to help towards consequent decision making. Thus, the landsat satellite images ETM+ 2002 and OLI 2014 have been used. They are completed by the topographic map, sector of Porto-Novo. By analyzing the results, the agricultural spaces of the plateau of Allada occupied a surface of 144,332 ha in 2014, either 71% of the hole space. It means there was a growth of 7% in comparison to 2002. 108,334 ha remained in culture or small fallow during 12 years. Therefore, about 36,000 ha constituted the result of the gains and losses on other land use units. In terms of gains, 17,629 ha of forests disappeared between 2002 and 2014 in the profit of agricultural zones. During the same period, the growth of the population had more lowered the availabilities of life crops. For example, 106 kg of available corn per inhabitant/yr in 2002 passed to 65 kg/inhabitant/yr in 2014, whereas according to the norms of the FAO, it should be of 134 kg/inhabitant/yr. then, it urges to intensify the production of food crops.

Index Terms— Sustainable Agriculture, Life crops, Satellite mage, Land cover, Demography.

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1 INTRODUCTION

The plateau of Allada is one of the plateaus of southern Benin. It is fully included in the Atlantic Department. It extends about 2037 km2 (Fig. 1) and is located in the sub-equatorial zone below the 6° 60' parallel where there is a bi-modal rainfall regime with disparities [1]. It is subject to demographic explosion with its food and environmental consequences. Indeed, with an annual growth rate of 2.68% between 1979 and 1992 and 5.06% between 2002 and 2013, the plateau of Allada population rose from 314,694 in 1979 to 717,813 in 2013 [2] i.e. a density of 352 inhabitants per square kilometer. It has almost doubled in 30 years**.**

In the mind to afford population growth, strategies have been adopted to meet food needs. These strategies are relative to the extension of cultivable areas (increasing areas to obtain enough products), increasing crop intensity (producing several times a year) and increasing yields (investing in a small area to obtain enough products) [3]. The increase in agricultural production is uneven between these three components [4] In the Atlantic department, agricultural production is increased by extending cultivated land, particularly at the expense of forests and savannas [5]. Populations, in search of arable and grazing land, exert significant pressure on land and lead to degradation of soils and wood resources [6]. Ahomadikpohou [5] has already noted in 2014 that the land is overexploited in all the communes of the department (including Plateau of Allada). This overexploitation of land leads to their degradation, which was confirmed by agro-demographic indices, which rose from 0.7 ha/inhabitant in 1992 to 0.44 ha/inhabitant in 2013 [5]. It is important to appreciate the different developments in agricultural areas over time and space in order to establish a scientific reference framework for sustainable agriculture [7]. This study focuses on the period from 2002 to 2014.

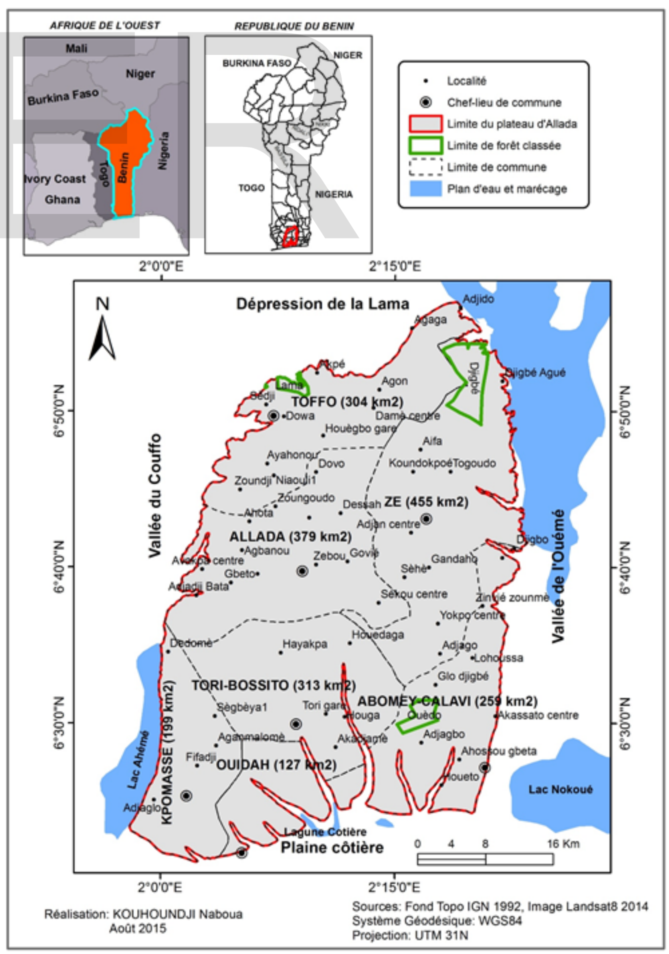

Fig. 1. Location of the study area

ISSN 2229-5518

2 Data and Methods

2.1 Data

The data used consisted of remote sensing and topographic maps.

Remote sensing products are derived from Landsat satellite images of 192-55 scene. These images are derived from the Enhanced Thematic Mapper Plus (ETM +) sensors on January 17, 2002 and Operational Land Imager (OLI) on December 28, 2014. They are at a spatial resolution of 30 m.

The topographic maps are those of Porto-Novo, sheets NB-31-XV-1d and NB-31-XV-2c. These maps are produced by the National Geographical Institute (IGN) France in 1968 and updated by the IGN Benin in 1992. They were used for the extraction of toponymical elements. These are complemented by fieldwork.

Demographic data are used to analyze the functional structure between the extension of agricultural areas and the increase in population. They relate to the last two censuses 2002 and 2013. They are obtained at the National Institute of Statistics and Economic Analysis (INSAE). Subsequently, yield data for major food crops are obtained from the Agricultural Statistics Direction of the Ministry of Agriculture, Livestock and Fisheries (DSA/MAEP). They were used to determine the availability of food crops in the study area.

2.2 Methods

The interpretation of satellite images is a process. The steps followed are described in the diagram of figure 2. They are three: the preparation of the image, the properly processing and the validation of the classification. All these operations are performed with Envi 5.1 software (for image processing) and ArcGIS 10.2 (for geospatial analysis).

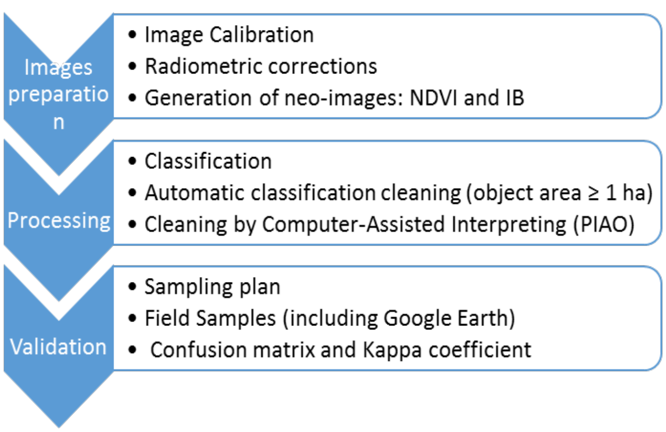

Fig. 2. Steps for processing satellite images

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The images concerned by the study are from different sensors and at different dates. The sensors record the luminances as a digital count. To be able to compare the images in pairs, they must be placed on the same radiometric bases. This is the preparation which consists initially of calibrating them and, secondly, of correcting the radiometric values. In addition, the discrimination of certain elements of land cover required the use of neo-images: calculation of the normalized difference vegetation index (NDVI) and the brightness index IB.

Still called the Tucker Index, NDVI is the most widely used vegetation index in remote sensing to identify vegetation types ([8], [9], [10], [11]). It gives information on the photosynthetic activity of the vegetation and therefore of its "green" state. It is calculated by:

$$NDVI = (NIR - R)/(NIR + R) \quad (1)$$

NDVI = normalized difference vegetation index
NIR = reflectance of the near infra-red band
R = reflectance of the red band

Since the study area images were taken during the dry season, the radiometric identification of bare soils is confounded with that of the clay spaces. The brightness index IB made it possible to discriminate them. It is calculated by:

$$IB = \sqrt{R^2 + NIR^2} \quad (2)$$

The next step in the process of interpretation after neo-images is the properly processing.

Image processing includes automatic classification cleaning and Cleaning by Computer-Assisted Interpreting (PIAO). The type of classification used is unsupervised. The method is ISODATA. The PIAO is done under ArcGIS 10.2. The encoding of land cover objects is based on the codification of the National Forest Inventory (IFN) of Benin. The classification was validated through the confusion matrix. This tool allowed to confuse the result of processing (classification) with the result of the samples (reference). This allow to identify well-classified observation points (having the same class in CLASSIFICATION and REFERENCE). The overall accuracy is the most relevant indicator for qualifying the result of the classification. It is obtained by dividing the number of pixels correctly classified (diagonal of the matrix) by the sum of the pixels of all the classes.

The 95% confidence interval can then be obtained from each land cover unit sampled by:

$$IC = \sqrt{p*(1-p)/n*1.96} \quad (3)$$

With
IC = confidence interval
p= accuracy of the unit of the land cover (result from confusion matrix)
n = total number of control points (samples)

The intensity of the link between the results of processing (classification) and those of observation (reference) is assessed by Cohen's Kappa coefficient (K) ([12], [13], [14]).

$$K = (P - Pe)/(1 - Pe) \quad (4)$$

With
K = Kappa coefficient
P = global accuracy (proportion of agree)
Pe = global error (proportion of desagree)

The interest of this indicator is that it introduces a kind of correction to take into account the fact that a certain proportion of agreement can be attributed to the fact of likelihood only.

The key proposed by Streiner and Norman [15] was used to interpret the value of K.

If K < 0.40: low agreement
if 0.40 ≤ K < 0.60: mean agreement
If 0.60 ≤ K < 0.74: good agreement
IF K ≥ 0.74: Excellent agreement

All these interpretation operations were applied to the image of 2014. The result of the segments obtained served as the basis for the computer-assisted photo-interpretation (PIAO) of the image of 2002. The change detection is performed using the transition matrix.

The population data are projected on the basis of the assumption of a geometric increase. Let P_n be the population of the last census (2013) and P_0 the population of the previous census (2002). We have:

$$P_n = P_0(1+t)^n \quad (5)$$

with t = yearly growth rate

The availability of food products, taking into account population and agricultural areas, was assessed on the basis of FAO and ONASA (National Food Security Support Office) standards (Table 1).

Table 1. Consumption standards and food production allocation

Products	Consumption (Kg/yr/inhabitant)	Post-harvest Loss (%)	Allocation part of surface*
Maise	134	20	0.46
Rice	11	50	0.06
Cowpea	4	30	0.02
Groundnut	4	50	0.02
Cassava	130	10	0.40
Sweet potato	12	15	0.04

Sources: Adapted from FAO [16]
* On the basis of crop area as priorities in the Department of Atlantique (MAEP).

These treatments generated results which are analyzed in the following section.

3 Results and Discussion

3.1 Validation of the classification of landsat image of 2014

The landsat8 OLI image of 2014 is processed and validated using the confusion matrix and the Kappa coefficient. The results of the confusion matrix are summarized in Table 2.

Table 2. Validation of the mage landsat8 OLI of 2014 by the confusion matrix

	CLASSIFICATION				*PARAMETERS*	
	Land cover unit	Agricultural zones	Non agricultural zones	TOTAL	User accuracy	Commission error
REFERENCE	Agricultural zones	1330	78	1408	94%	6%
	Non agricultural zones	136	856	992	86%	14%
PARAMETERS	TOTAL	1466	934	2400		
	Producer accuracy	91%	92%		91%	
	Omission error	9%	8%			9%

A total of 2400 points were randomly sampled. Comparison of the classification with the field data showed that the overall accuracy was 91%. That means 91% of the pixels sampled are well classified. The overall error was 9%. These indicators show that the results of the classification are of good quality. The user accuracy obtained on agricultural areas was 94% with a confidence interval of +/- 1.19%; While the producer precision on these same units gave 91% with a confidence interval of 1.49%. The difference between automatic classification and field observation is 3% (minimum value). For non-agricultural areas, user accuracy was 86% (with a confidence interval of +/- 2.14%), while producer accuracy provided 92% (with a confidence interval of 1.77%).

Overall, the Kappa K coefficient obtained was 0.90. This value is greater than 0.74. According to the key proposed by Streiner and Norman [15], there is an excellent agreement between automatic classification and field data. After this validation, it's possible to produce the distribution map of the units of land cover.

3.2 Spatial distribution of agricultural areas in 2014

The interpretation of the landsat OLI image of 2014 revealed 144,332 ha of agricultural areas compared to 59,342 ha of non-agricultural areas, i.e. 71% and 29% respectively (Fig. 3).

Agricultural areas consisted mainly of annual crops, fallow land and young crops grown in subsistence crops. The young plantations are mostly teak gardens and palm plantations. Non-agricultural areas consist of tree plantations, marshy formations, water bodies and agglomerations.

ISSN 2229-5518

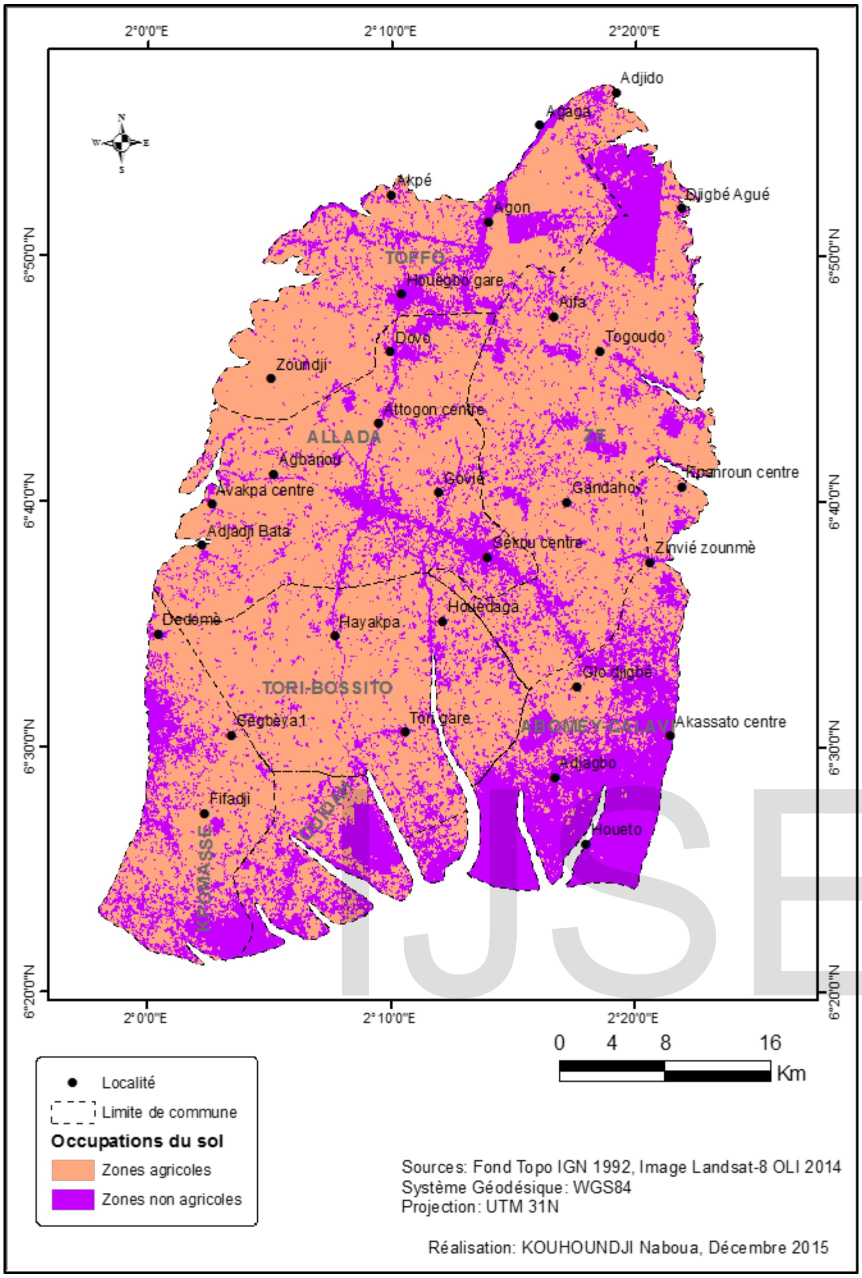

Fig. 3. Agricultural and non-agricultural areas of the Plateau of Allada in 2014

Among the seven municipalities that cover the plateau of Allada, Ouidah recorded a low agricultural area rate of 4.41% (Fig. 4). Its cultivable spaces were found in Savi, Gakpé, and somewhat in Pahou. The part near the coastal lagoon of this commune was occupied by non-agricultural units. The mune of Ouidah was preceded by Abomey-Calavi (5.92%). The agricultural areas of this commune were concentrated in Glo-Djigbé and Zinvié. The municipality of Zè held the est proportion of the agricultural areas of the plateau with 24.08%. It was ahead of Allada by about 3%. The non-agricultural areas constituted predominantly of tions, forests/ plantations, and were found in a higher tion in the municipality of Abomey-calavi, i.e. 29.30% (Fig. 4).

This shows the degree of humanization of that commune. It was followed by Zè and Allada with 18.07% and 13.02% respectively. The smallest proportion of non-agricultural land was in the municipality of Tori-Bossito (7.06%). This made it the less anthropized community.

These balances for 2014 were the results of the progressive and regressive evolutions of the previous years, including that of 2002.

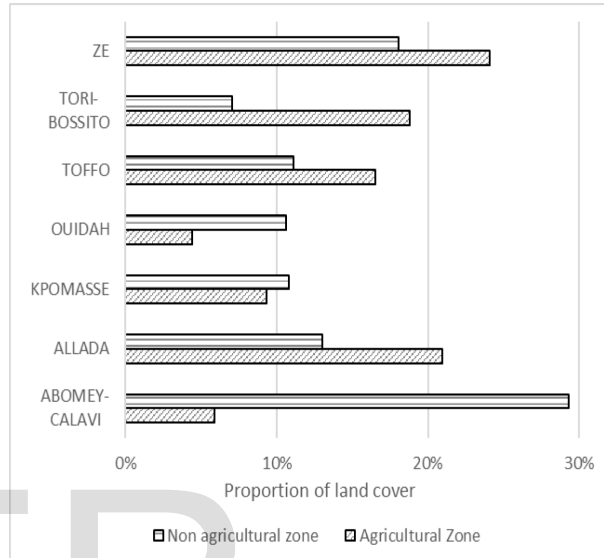

Fig. 4. Breakdown of land cover by commune in 2014

3.3 Spatial distribution of agricultural areas in 2002

Agricultural areas occupied the largest area of the plateau of Allada in 2002 (Fig. 5). Their surface was about 129,749 ha compared with 73,926 ha for non-agricultural areas. The South ly the east and west extremes), the center and the north of the study area were populated by non-agricultural areas, mainly agglomerations and bare soils (Fig. 5).

These were the most populated places at the time. These are the communes of Abomey-Calavi in the south-east, Kpomassè in the south-west, Allada in the center and Toffo in the north. Agricultural areas accounted for 64% of the territory, while non-agricultural areas accounted for only 36% (Fig. 5).

Agricultural areas were almost in an equal proportion in Ze, Tori-Bossito and Allada with 20.32%, 18.68% and 18.67% respectively (Fig. 6). The communes of Toffo and Abomey-Calavi came after these first. Their proportions were 16.34% and 12.13% respectively. The commune of Ouidah was the least in agricultural space (about 5% of the agricultural areas of the hole plateau).

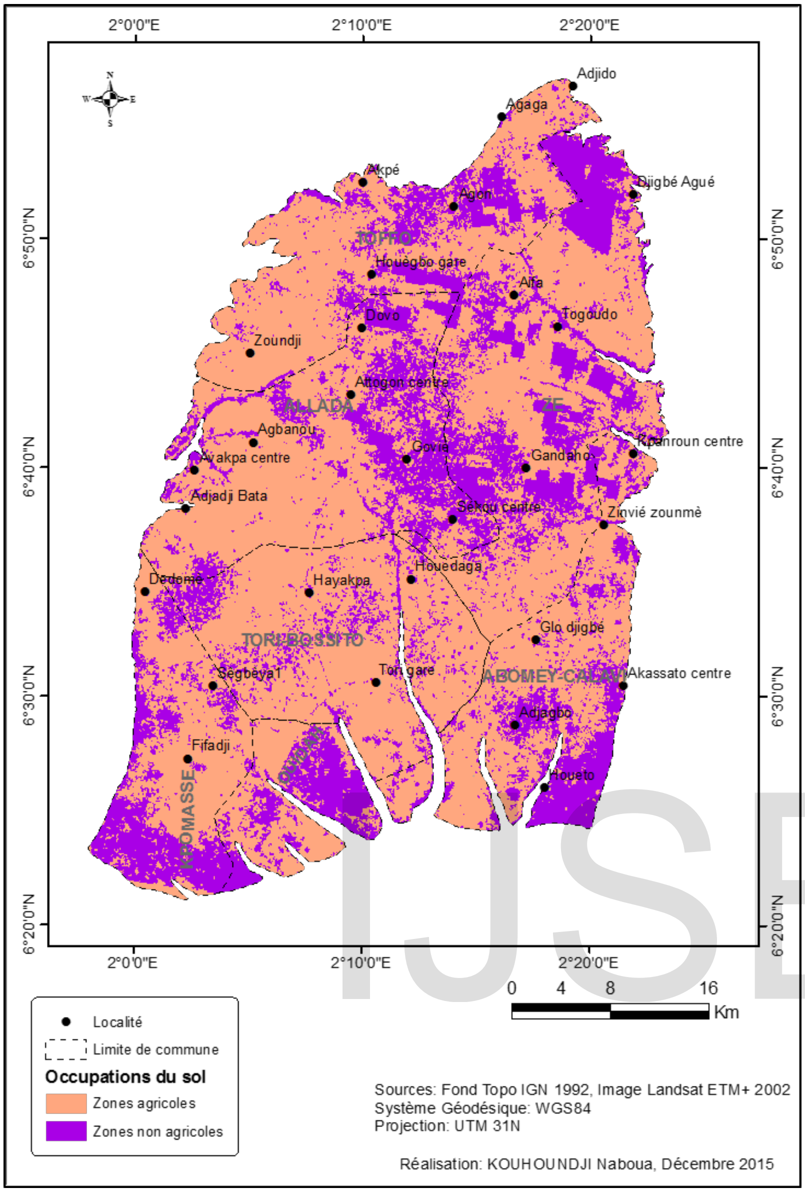

Fig. 5. Agricultural and non-agricultural areas of the Allada Plateau in 2002

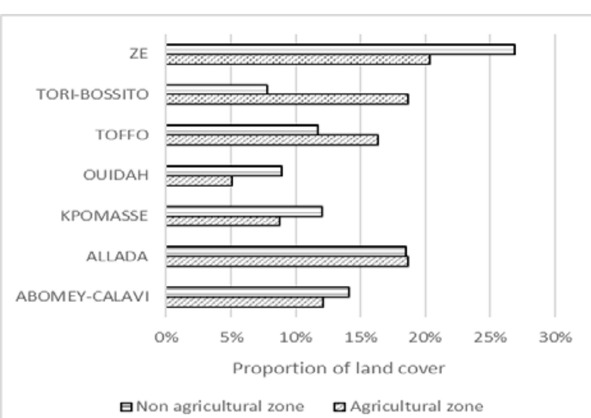

Fig. 6. Breakdown of land cover by commune in 2002

In terms of non-agricultural areas in 2002, the municipality of Zè still had the lead with 26.90% of the hole territory of the plateau. It should be noted that this was mainly the protected forest of Djigbé and public and private plantations. Then, came the communes of lada and Abomey-Calavi with 18.53% and 14.11% spectively. Tori-Bossito was the commune with less non-agricultural space valued to 7.81% of the entire plateau (Fig. 6).

Between 2014 and 2002, there were stable and able locations resulting from regression and sion movements of land use units.

3.4 Change of agricultural areas between 2002 and 2014

The size of land-use units varied in time and space. After analyzing the 2002 and 2014 agricultural and non-agricultural maps presented above, there was gains and losses from land cover units. The status of these changes is presented in the following table.

Table 3. Agricultural and non-agricultural transition matrix between 2002 and 2014.

Land cover unit (ha and %)		2014		TOTAL
		Agricultural zones	Non agricultural zones	
2002	Agricultural zones	108334 (53%)	33509 (17%)	141843 (70%)
	Non agricultural zones	30080 (15%)	31798 (15%)	61878 (30%)
TOTAL		138414 (68%)	65307 (32%)	203721 (100%)

Table 3 shows that 108,334 ha of agricultural land, i.e. 53% of the study area, remained unchanged tween 2002 and 2014. These areas were distributed throughout the Study area, especially in western (north to south) and the northeast part (Fig. 7). For 12 years, these places remained permanently under cultivation or small fallow. This can degrade soils by altering their structure and texture. Non-agricultural areas remained unchanged in 31,798 ha, or 15% (Table 3). They were found mainly in the northeast (protected forest of Djigbé), in the southeast (Abomey-calavi agglomeration) and some other scattered plantations and agglomerations (Fig. 7).

Between 2002 and 2014, 33,509 ha of agricultural areas (17% of the territory) were converted into non-agricultural zones (Table 3). These locations were more visible in the commune of Abomey-Calavi, along the road section of Glo-Djigbe-Sékou-Allada-Attogon-Houégbo-Agon and within public and private plantations (Fig. 7). These areas were converted into agglomerations and assimilated, and plantations. Meanwhile, 30,080 ha (or 15%) of non-agricultural areas were converted into agricultural areas (Table 3). These were mainly plantations in the communes of Zè, Allada and Toffo (Fig. 7). There were 17,629 ha of forests that disappeared between the two dates. All these movements had repercussions on the food supply of the plateau.

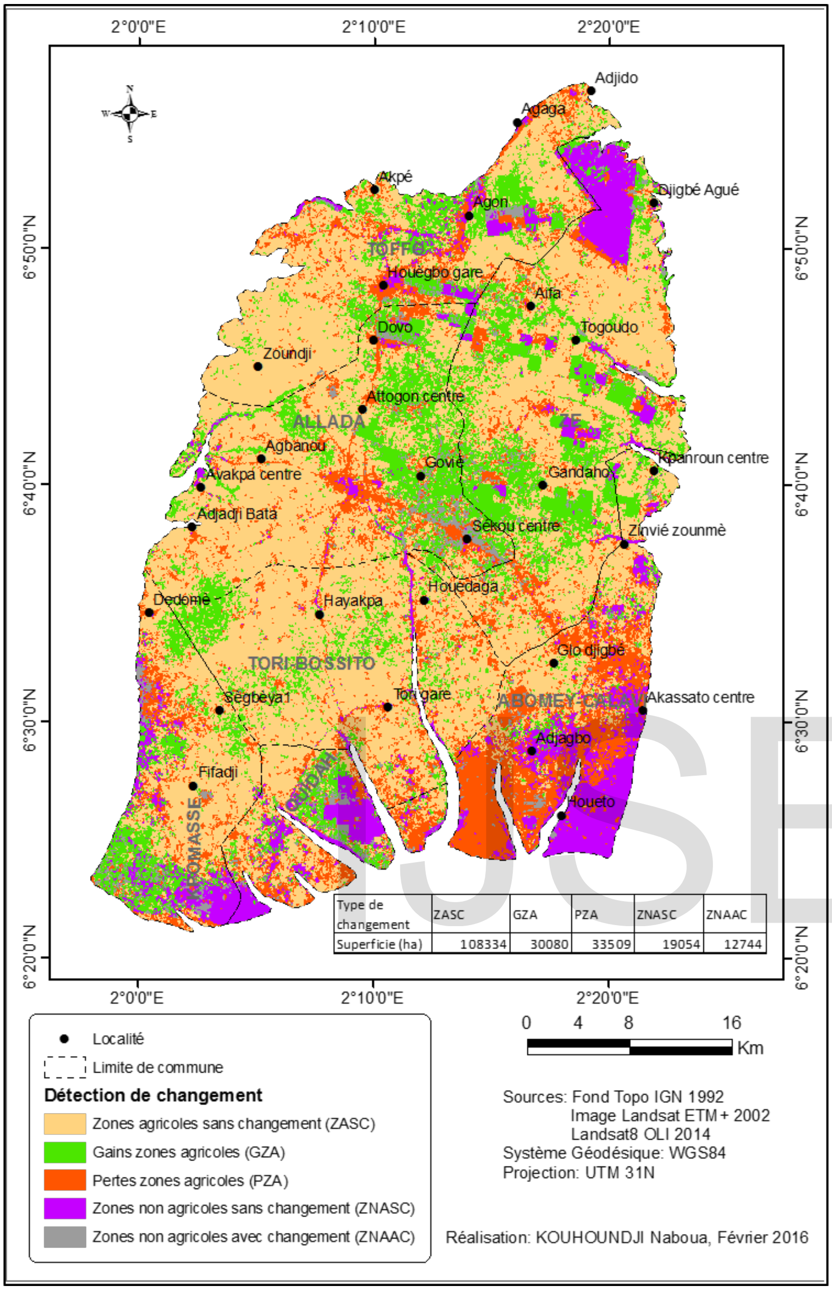

Fig. 7. Change in land cover of the Plateau of Allada between 2002 and 2014

3.5 Food supply availability in 2002 and 2014

Between 2002 and 2014, the availability of food products for the populations of the plateau of Allada experienced fluctuations following the dynamics of the agricultural zones. On the basis of consumption standards published by FAO (see Table 1), the availability of the main food crops in 2002 exceeded FAO standards for sweet potato and cassava crops. For other crops, there was a deficit (Fig. 8). In 2014, the situation is more worrying. Availability of major food crops is below FAO standards, except cassava and somewhat sweet potato (Fig. 8). The latter are not as popular with the population as maize and rice. This explains in part the imports of food products made on the sector of study of which Goudjon [17] spoke. Deficits in the availability of food products were also noted by Ahomadikpohou [5] in the Department of the Atlantique.

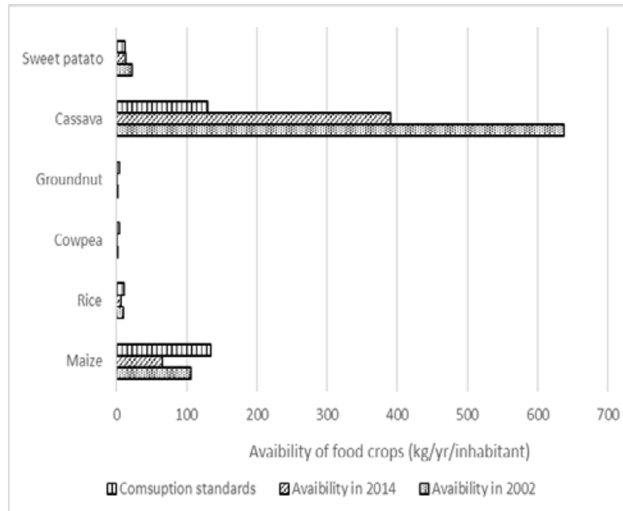

Fig. 8. Availability of food crops on the plateau of Allada between 2002 and 2014

Taking into account the plantings of the pineapple crop that is growing in recent years [18], the situation on the availability of food products would be more critical. Indeed, producers adopt the cultivation of pineapple more for its resistance to periods of dryness due to climate variability.

4 Conclusion

The study on the change of the agricultural zones of the plateau of Allada allowed to account for the extension of the agricultural areas between 2002 and 2014. The degradation of the grounds following their exposure to bad weather was apprehended. These changes had a negative impact on the food supply of the population. Sustainability of agriculture in the study area requires that forestry standards be respected in agricultural advice, especially in the context of climate variability or change. To do this, there is a strong involvement of the ministry in charge of agriculture in the land-use projects so that the supervisors can follow the producers and advise them in that way. At the same time, scientific methods for the sustainable use of agricultural resources must be sought by following a geographical information system, since all the physical elements of an environment are interwoven with one another.

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