



Case Study

Study of land dynamics in Benin: Case of the Municipality of Allada

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Abstract

The present study on land dynamics from GIS tools and remote sensing was conducted in the municipality of Allada in southern Benin. The objective is to show the evolution of the habitats according to the population growth and its land situation in relation to the various urbanization operations on the horizon 2050. The methodological approach adopted focuses on documentary research, socio-land survey and diachronic cartography based on satellite imagery of 1986, 2000 and 2016 and SIG. From a survey carried out with Idrisi Selva software, the directions of spreading at the horizon 2050 were determined. From 1986 to 2016 the population of the Commune increased from 62880 to 176735 while the area occupied by the habitats increased from 409.87ha to 1008.36ha. Five areas to be developed as a priority have been defined.

Keywords: Land dynamics, demography, sprawl habitats, Allada, SIG, Idrisi Selva.

Introduction

Most developing countries, including Benin, have land problems¹. These problems arise in particular in terms of availability and rational use of land. The causes related to this question concern urbanization, demographic growth, dualism of land rights² and obsolescence (cessation of a custom, a law) of laws and regulations (Ministry of Urban Planning, Housing, Land Reform and the fight against Coastal Erosion ‘‘MUHRFLEC’’). In order to control these urbanizations, developing countries have put in place several planning policies that result in several operations, including land consolidation. In Benin, several localities benefit from land consolidation. Among them is the municipality of Allada.

The current municipality of Allada, the administrative center of the Atlantic Department, experienced a population growth rate of 2.95% in 2013 (General Population and Housing Census ‘‘RGPH 4’’). This rate is higher than that of Cotonou which is 0.18%. An analysis of the different numbers obtained by district shows a high concentration of populations in some districts of the Commune. There is also anarchic occupation of the territory of the Commune. This situation led the authorities of the Common to achieve several consolidation operations to reorganize the agglomerations. In addition, uncontrolled urbanization has several consequences³. However, the zones to be developed are defined without taking into account the direction of the spreading. A new direction of urbanization, according to its land use and urban spreading, would be an asset for its development.

Background and justification: Land is the support of all human activity⁴.

Its use and management is becoming a crucial issue in African countries⁵. In this way, different development policies are developed, thus giving birth to the urban and rural environment. Urban areas are in principle also characterized by a good organization of land through land operations including land consolidation. Urban areas are experiencing high population growth because of security, access to public services, jobs, concentration of power and economic activities.

In Benin, Inter-Ministerial Order No. 038 / MUHA / MDGLAAT / MERPMEDER / MCTIC / DC / SGM / DGDU / DUAL / SA, defining the minimum requirements for subdivision operations and urban land consolidation operations in the Republic of Benin, in Article 9, defines urban land consolidation transactions as operations having for object in a given area, the modification of the limits and the capacity of the land properties as well as easements and the charges which are attached to them, with a view to the realization of works of development and equipment of interest collective (opening and construction of roads, installation of drainage, sewerage, electricity, drinking water, telecommunication networks, etc.).

These land operations are taking place in several communes of Benin including the municipality of Allada mainly in the districts of Allada-center and Sékou. They will make it possible to organize these districts well, to house the populations who migrate there and to make them favorable to the economic activities. These operations therefore become an economic and social issue and must be well oriented because poorly organized urbanization creates enormous difficulties⁶.

Material and method

For this study multi-source data that has been processed using multiple software packages have been used. Some were collected in the field.

Materials: Several materials are needed for this study. Apart from office equipment, some field equipment including Gamin Dakota 20 brand navigation GPS, for the identification of different land-use units, and CHC brand dual-frequency GPS / GNSS, for the georeferencing of the different land consolidation plans, were used. This material made it possible to obtain the Landsat satellite images, land consolidation plans and the numerical model of Allada Commune.

Methodological approach: The methodological approach adopted is summarized in three points: i. Desk research, ii. Estimated building rates in the land consolidated areas of the Commune, iii. Identification of the probable wetlands of the Commune, iv. Elaboration of the prediction map by horizon 2050.

Literature search: This step made it possible to obtain the maximum of information on the theme. For this, existing documents have been consulted and information collected in the field. This information relates to the study area. Further information was obtained from the DST of the Marie d'Allada, at the FLASH library at UAC, IGN and INSAE. Information collected on the internet was also used. Technical data was produced through fieldwork.

Data collection and analysis: Images: Images downloaded from the website "earth explorer usgs gov" are in GEOTIFF format. These are images that have undergone geometric corrections.

Table-1: Land sat Images Download⁸.

Data	Characteristics
Land sat image (TM, ETM +, OLI) from 1986, 2000 and 2016	15 m (Panchromatic) 28.5 m (Multi spectral)

Land consolidation plans: All the plans of the nineteen consolidation operations are collected. They were scanned and georeferenced. The points determined were identified by dual-frequency GPS / GNSS CHC (series 900) with a two-hour observation time with reference to the permanent station of Cotonou. The method of static GPS survey with post-processing has been adopted. The measurements obtained were subjected to the tolerance allowed by the interministerial decree n°0068 / MUHRFLEC / DC / SGM / IGN / DGURF / SA, fixing the norms and specifications and techniques applicable to the topographic and cartographic works in the Republic of Benin in order to appreciate the result of georeferencing. This tolerance is defined by the following formula:

$$T = \text{Value réelle} - \text{Valeur vraie} / \ll (0,1 * E_c) \text{mm} + 1 \text{ppm} ;$$

With E_c = scale factor, 1ppm = 1mm per kilometer

The digital terrain model: The MNT of the Commune of Allada has a precision of 1m in altimetry. It comes from the data returned to IGN Benin through the Millennium Challenge Account-Benin project (MCA-Benin). In order to verify the accuracy of this MNT, surveys of field points are taken. The points were identified then sketch sheets were developed for a good location of the points. These readings are made with a CHC series 900 dual frequency GPS. The observation of the points was made in static mode with two hours of observation per point.

The Master Plan of Communal Development (MPCD): The exploitation of the MPCD was very useful because this document made it possible to become acquainted with the major assignments of the territory of the Commune.

Estimated rack rates: The digitization of buildings makes it possible to have polygons whose surface we can easily express. The areas of the polygons will make it possible to highlight the occupation rates of the land consolidation zones.

Table-2: Estimation of built-up areas after land consolidation.

Consolidated zone	Consolidated area	Buildings area	Percentage in occupation
Secteur 6	161ha	19ha50a72ca	12%
Group A	97ha	7ha07a92ca	4.39%
Group B	137ha	20ha07a82ca	14.66%
Group C	21ha	4ha15a84ca	19.80%
Former prova	100ha	3ha27a86ca	3.28%
Wagléta	139ha	93a92ca	0.68%

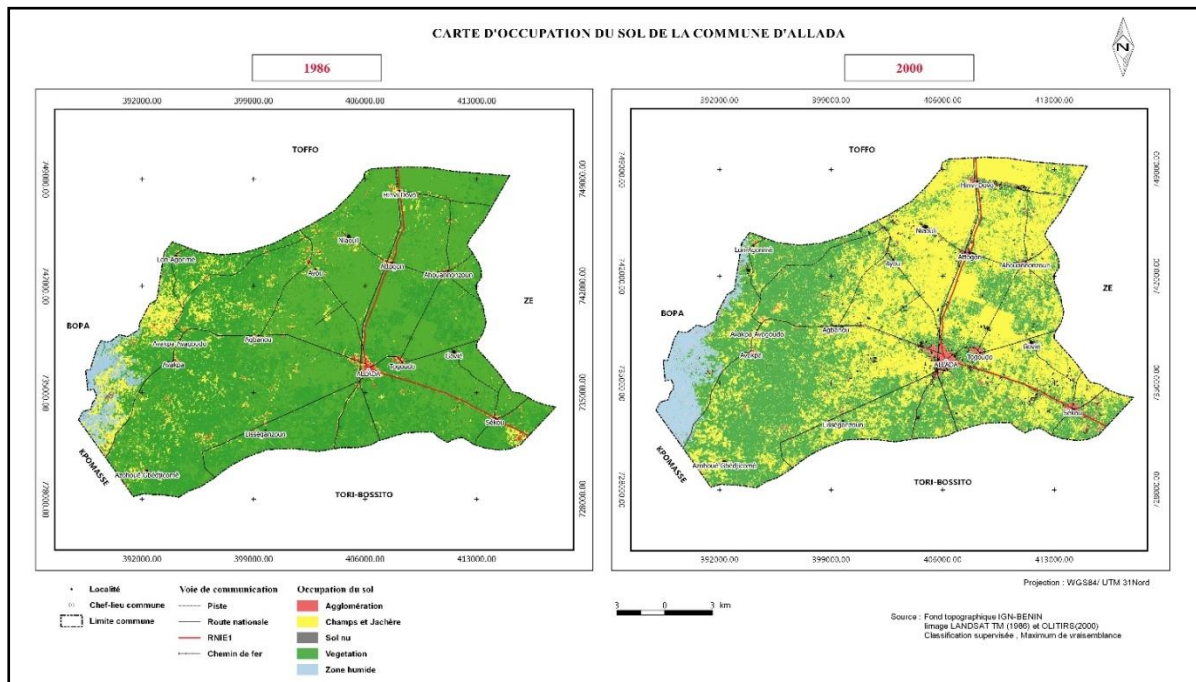
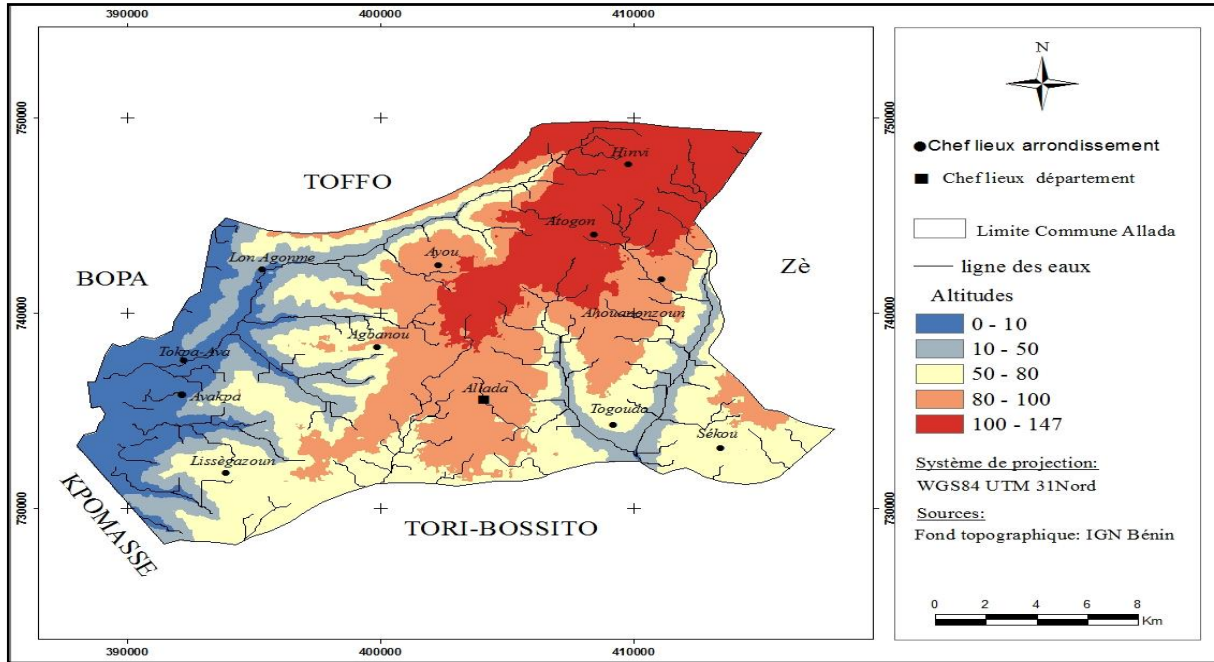
Identification of wetlands: From the Global Mapper software, the level curves have been regenerated in order to obtain the natural flow direction of the waters and the slopes of the natural terrain. There are several criteria for defining wetlands, but in this study we have equated wetlands with low elevation areas. The Figure-2 is made:

Elaboration of the prediction map by horizon 2050: The LCM module of Idrisi allowed identifying the evolution of the different units of occupation of the ground. The Markov chain offers the opportunity to know this evolution over a period of thirty-four (34) years, that is to say the period 2016-2050. This evolution was made considering that the increases in units of occupation observed between 1986 and 2016 are maintained.

After having created the project, it is necessary to ensure the correspondence of the different classes, that is to say that the different units of occupation of the ground must have the same identifiers. It is necessary to introduce the results of the classifications then to enter the two years and the period on which one will make the prediction.

Results and Discussion

Land dynamics. Land cover from 1986 to 2000 and 2000 to 2016.



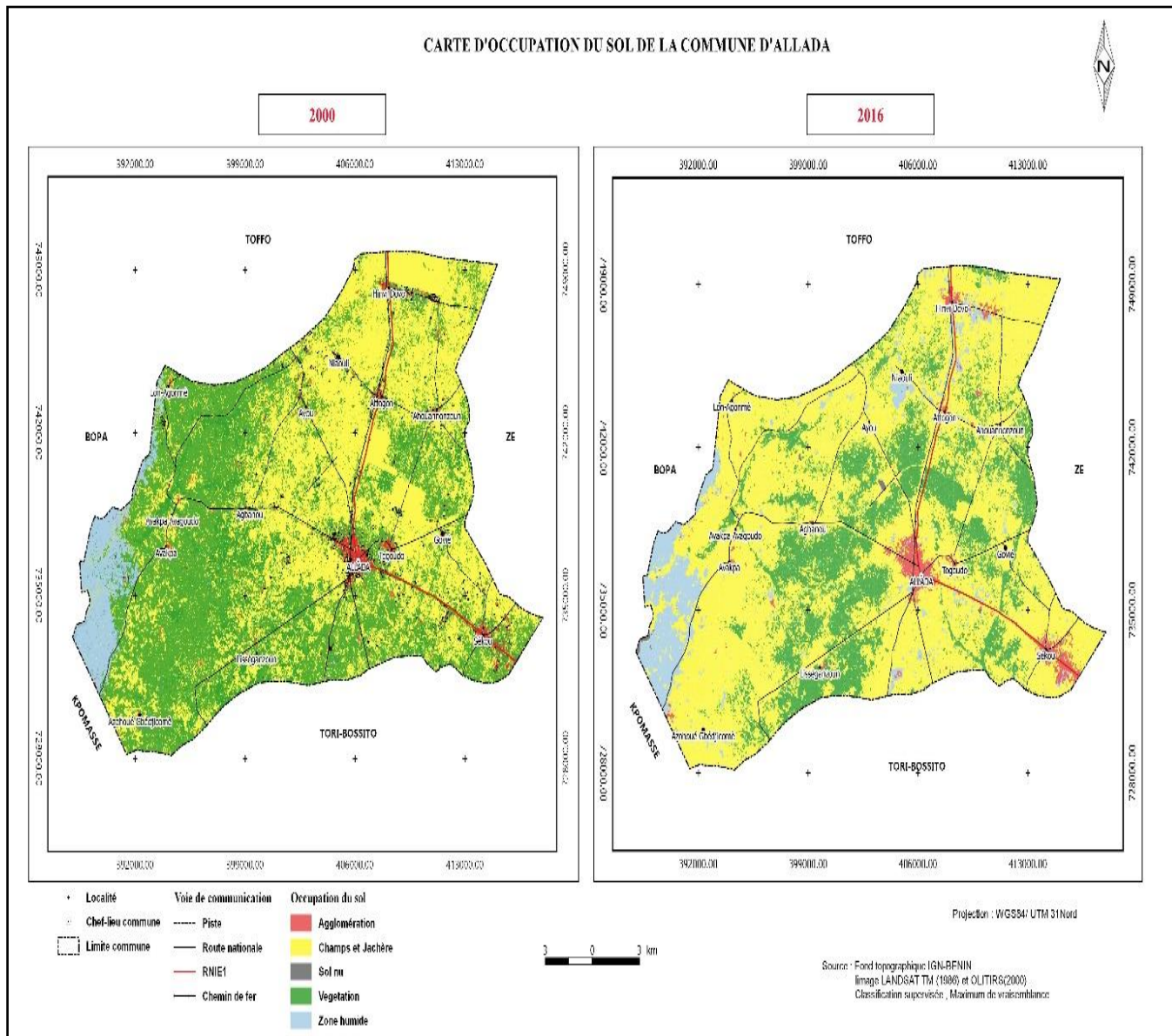


Figure-4: Land Cover Map 2000 to 2016

Table-3: Comparison of land occupations in 1986, 2000 and 2016.

Classes	1986 (%)	2000 (%)	2016 (%)
Agglomeration	1.08	2.29	2.65
Vegetation	89.10	51.84	22.24
Fields and fallow	7.71	41.29	68.64
Bare soil	0.07	0.01	0.19
Humid zone	2.04	4.57	6.28

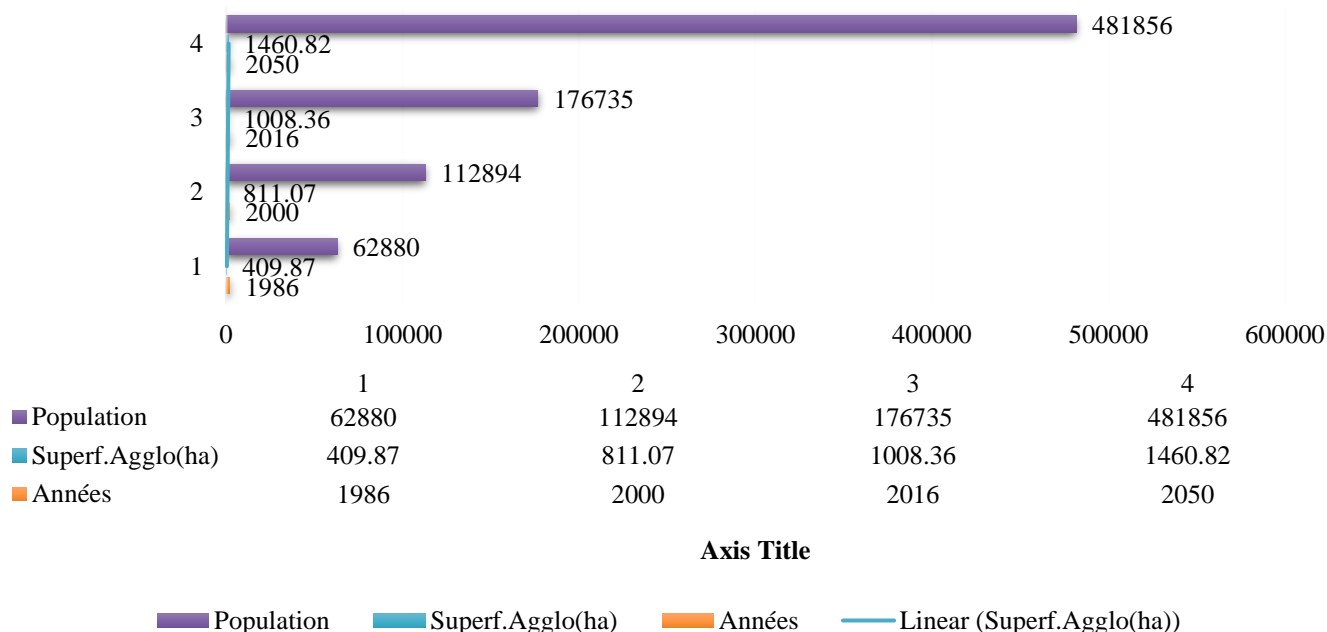


Figure-5: Comparison of Occupied Area and Population.

The analysis in Figure-5 shows that demographics grow faster than the occupied area. There is therefore a high concentration of the population in places.

Three types of results can come from the study of different units of land occupation. Units may undergo changes, either conversions, or remain unchanged. The results of the diachronic analysis carried out show that the land use classes have undergone conversions. Many of them have changed their class, for example vegetation giving way to agglomerations and fields. The class "vegetation" includes the different types of savannas and the few existing forests in the Commune. The vegetation experienced an average annual regression of -4.63% of its area over the entire study period. It occupied 89.10% of the surface of the Commune in 1986 but in 2016 this rate was 22.24%. This regression can be explained by the increase of populations in rural and urban areas, and by the development of economic and agricultural activities. Anthropisation is therefore the essential cause of this regression. This anthropization can be done by transforming natural environments into fields. The unit of land use "field" includes fallows, crops and plantations. The area occupied by the fields has increased enormously since the year 2000; the annual average growth rate is 11.99% from 1986 to 2000 and 7.29% over the thirty years. This growth is justified by the population growth which goes from 62880 inhabitants in 1986 to 176735 inhabitants. Thus the agricultural area increases with population growth. The analysis of the occupation of the Commune reveals the presence of wetlands. They are characterized by moisture due to the presence of water and flood areas. They experienced an average annual increase of 3.91%. Occupation of the land consolidation areas

This progression is favored by flooding or drought or lack of housing in wetlands. The classes called "bare soils" are also part of the units of occupation. They essentially comprise bare surfaces. They increase by 3.12% on average annually over the period from 1986 to 2016. This increase may be due to the increase in built-up areas. Built-up areas or agglomerations are also part of land-use units. They constitute the essential elements for the appreciation of the occupation of the grounds. The "agglomeration" class essentially groups together the built-up areas. This area increases by 3% as indicated by its average annual rate over the period from 1986 to 2016. In 1986, agglomerations occupied 1.08% of the Communal area. This percentage was 2.65% in 2016. This shows an evolution of the space occupied by the agglomerations and by the population. However, the low land absorption rates obtained in 1986, 2000 and 2016, which were 0.65%, 0.72% and 0.57%, show a high concentration of agglomerations in some areas of the Commune. The comparison diagram of population and inhabited area shows a population explosion on small areas. It shows that population growth is far beyond the area occupied by agglomerations. An analysis of the different maps produced shows a concentration of agglomerations in boroughs with high population growth. This concentration was noticed in the central district of Allada in 1986, in the districts of Allada-center, Hinvi, Togoudo and Sékou in 2000, and in the districts of Allada-center, Togoudo, of Hinvi, Sékou and in the district of Lissègazoun in 2016. It can therefore easily be deduced that population growth far beyond the inhabited area even in urban and peri-urban areas. The spread of the built-up area is very slow.

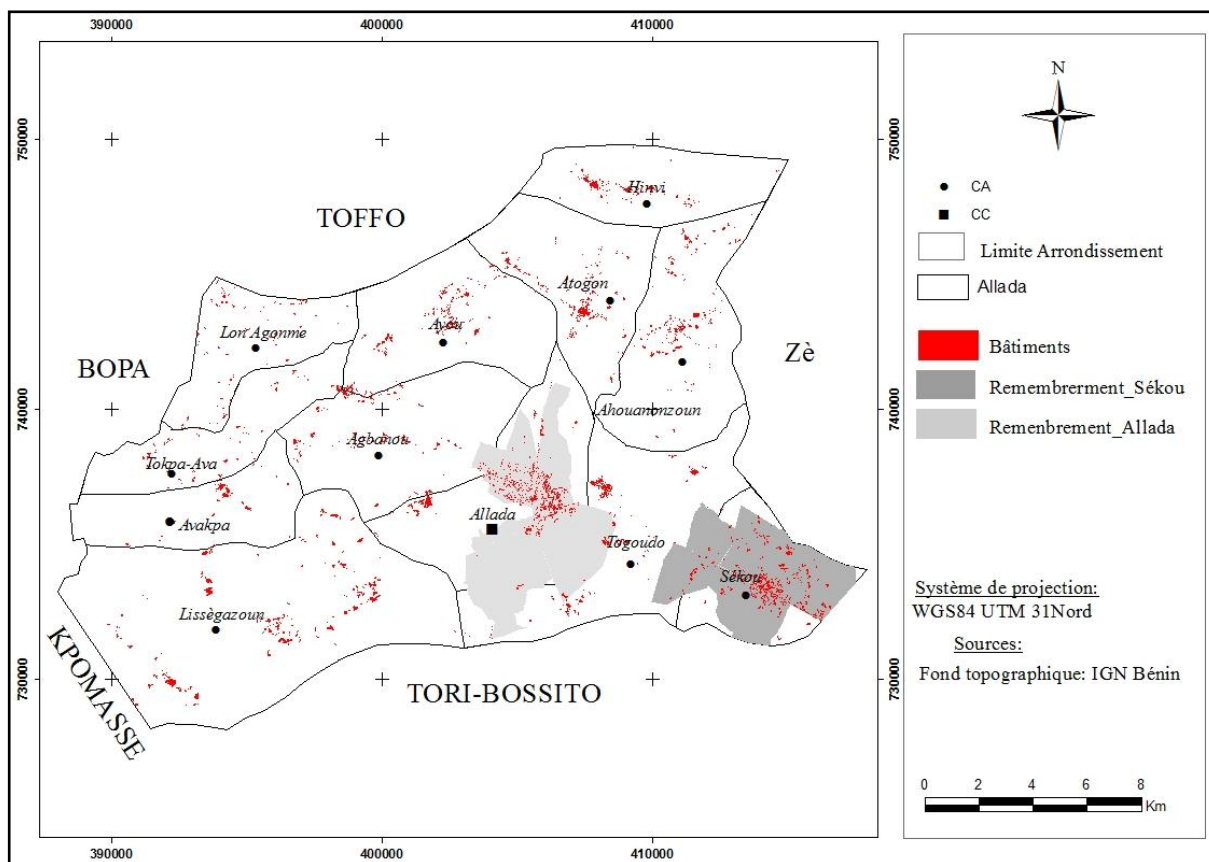


Figure-6: Map of the buildings of the municipality of Allada.

Table-4: Estimation of built-up areas after land consolidation.

Consolidated zone	Consolidated area	Buildings area	Percentage in occupation
Sector 6	161ha	19ha50a72ca	12%
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Occupancy rates for fully developed areas range from 0.68% to 19.80%. The regrouped zones, that is, sectors "6", "A", "B" and "c" are respectively built up to 12%, 4.39%, 14.66% and 19.80%. The developed areas of Ex-prova and Wagléta are occupied at 3.28% and at 0.68%. The various georeferencing operations carried out and the digitization of the buildings make it possible to obtain the truly consolidated surfaces and those being reconsolidated. Of the twelve boroughs in the Commune, only one district had entirely consolidated areas. Six zones or sectors are fully consolidated and make a total area of 655ha

with an occupancy rate of 54.81%. Consolidation of Unit "B" has been completed for 16 years but only 14.66% of the area is built. These different rates show a very low occupation of fully consolidated areas. The non-vitalization of consolidated areas may be one of the causes of slow occupation. In fact, since the end of the land consolidation works, the following equipment has been completed: a CEG (A sector consolidation), two primary schools (B sector consolidation), a forestry station (Ex-prova consolidation) and a court (land consolidation sector B).

This reduced number of equipment will not allow the installation of populations. To this is added the mode of acquisition of the land. According to the MPCD, "Aboriginal families remain the big landowners". The latter do not necessarily feel the need to erect buildings given the large amount of agricultural land in their possession. This situation reduces land transactions which do not favor the installation of new buyers. However, some parcels are owned by suspected owners who prefer to keep it instead of exploiting it. It is strongly clear that the communal authorities force the purchasers of parcels to respect the mechanism of site preparation envisaged by the land code property.

Priority areas to develop: Prediction of land use: According to Table-5, the probability of changing agglomerations is 0.2620%. That of fields and fallow land is 0.7183%. The bare soils will experience a very slight evolution that is 0.0262%. Vegetations and wetlands will increase significantly by 0.196% and 0.7050%.

The prediction of the units makes it possible to obtain their "evolution or regression" which are represented on the Figure-7. The areas of the different data layers obtained are grouped together in the Table-6.

Table-5: Percentage Transition Probability Matrix.

	Agglo	Field	sln	Vegeta	Zhu	Total
Agglomeration	0,2620	0,1127	0,0045	0,5859	0,0350	1
Vegetation	0,0517	0,1966	0,0073	0,5436	0,2008	1
Bare soil	0,0187	0,0000	0,262	0,1021	0,8531	1
Fields and fallow	0,0320	0,1862	0,0004	0,7183	0,0630	1
Humid zone	0,0359	0,0145	0,0211	0,1836	0,7450	1

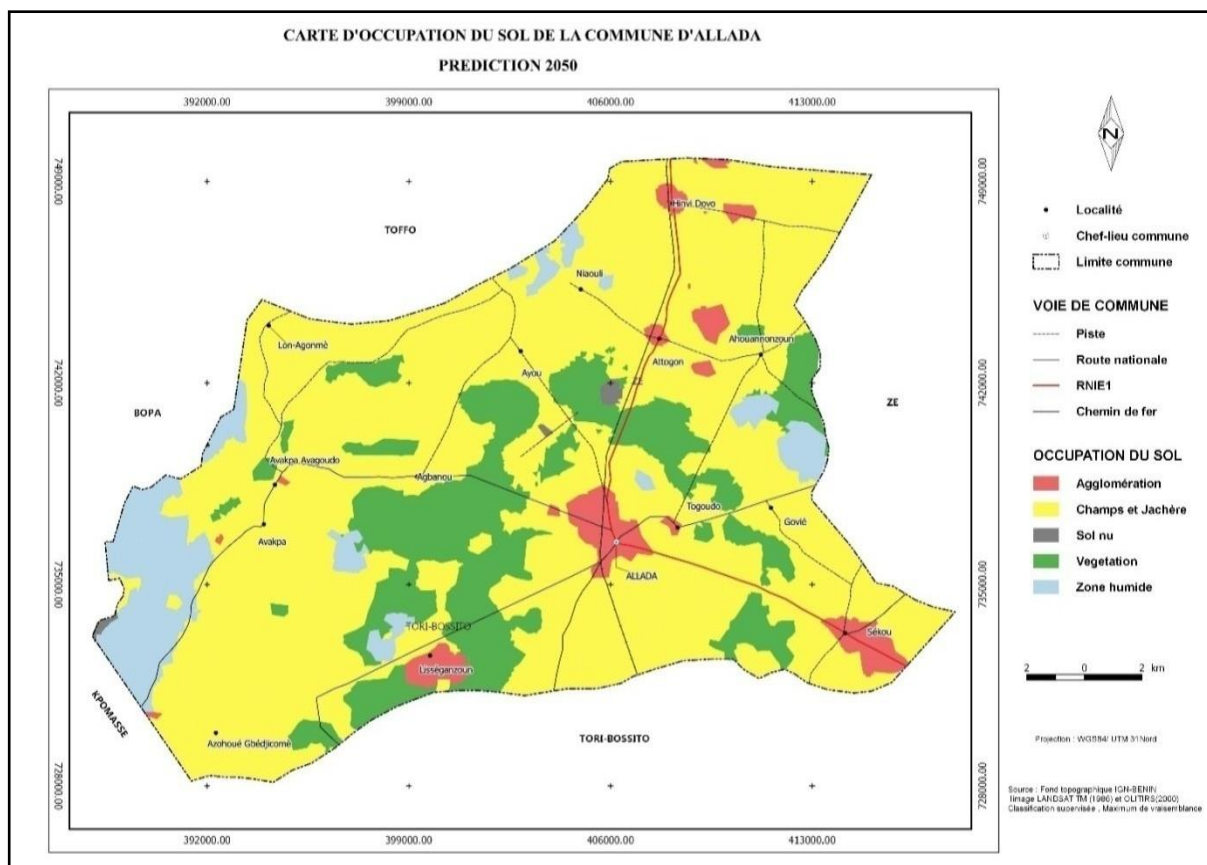


Figure-7: Prediction map to 2050.

Average annual rate of spatial expansion (Ta):

Ta3: Average annual rate of spatial expansion over the years 1986-2016 in%.

Ta4: Average annual rate of spatial expansion over the years 2016-2050 in%.

Table-6: Ta on the period 1986-2016 and 2016-2050.

Classes	SUP 86	Ta3 (%)	SUP 2016	Ta4 (%)	SUP 2050
Agglomeration	409,87	3	1008,36	1.09	1460,82
Vegetation	33926,23	-4.63	8467,43	-0.74	6589,15
Fields and fallow	2934,98	7.27	26013,77	0.11	27027,30
Bare soil	27,96	3.12	71,31	0.88	96,33
Humid zone	779,16	3.91	2517,33	0.35	2840,07

The results obtained easily show an increase in the area occupied by the population. This area increases from 1008.36 ha in 2016 to 1460.82 ha. The average annual rate of spatial expansion is 1.09%. The area occupied by vegetation decreased from 2016 to 2050 with an average annual growth rate of -0.74% instead of -4.63%. As for the fields, they have increased in size. The average annual rate of expansion of "bare soils" decreased from 3.12% to 0.88%. The area occupied by wetlands has grown.

Comparison of the different indicators for the "Agglomeration" unit: After analysis of the table we notice a regression of the coefficient of absorption of land which goes from 0.53% to 0.15%. However, there is a regression in the rate of land consumption which decreases from 0.65% to 0.57% over the period 1986 to 2016 and from 0.57% to 0.30% from 2016 to 2050.

The different coefficients make it possible to assess the average annual evolution of "agglomerations". A comparison of the

annual average rates calculated over the period from 1986 to 2016 and from 2016 to 2050 shows a decline in agglomerations. The land absorption coefficient is 0.3% instead of 0.53%. The land consumption rate calculated for the year 2050 is very low. The area and population ratio is very low, which reflects a concentration of habitats and not a spread. Figure-17 shows the areas at low altitudes and shows the direction of water flow. Indeed, several criteria are needed for the identification of wetlands. It can be done from altitudes, soil types, groundwater level, slope and by visual interpretation of a high resolution image. Probable wetlands are areas of low altitude. It will be necessary to respect the 25m of easements around watercourses. Probable wetlands and easements of 25m, should not be developed for housing. According to the MPCD (Master Plan of Communal Development) of the Commune, all the boroughs of the Commune must be consolidated within a radius of four (4) kilometers by 2015. This situation will lead to the disappearance of agricultural areas to the detriment of consolidated areas with a very low rate of agglomerations. To avoid this situation, the priority areas must be identified and consolidated. Their choice must take into account the results of the survey and the probable wetlands. A superposition of the result of the prediction and the MNT, allows obtaining the priority zones to be consolidated while sparing the probable wetlands. Thus, the districts of Allada -centre, Sékou, Attogon, Hinvi, Ahouanzoun and Lissègazoun will have to be consolidated as a priority. The other districts should not be consolidated by 2050. The Commune must make all the consolidated zones and those in the process of consolidation in order to facilitate the settlement of the population. It must not initiate new consolidation operations. New land consolidation operations will be initiated thanks to the results of a new prospection that will be carried out after 2050.

Ta: Average annual rate of spatial expansion

Cat: Land absorption coefficient

Tct: Land consumption rate

Summary map: It is the result of the combination of the land use maps of 1986, 2000 and 2016, the exclusion of wetlands and the consideration of the guidelines of the MPCD (Master Plan of Communal Development).

Table-7: Calculation of Ta, Cat and Tct.

Date	Surface area	Population	Ta	Cat	Tct
Period 1986-2016					
1986	409,87	62 880	3.00	0.53	0.65
2016	1008,36	176735			0.57
Period 2016-2050					
2016	1008,36	176735	1.09	0.15	0.57
2050	1460,82	481856			0.30

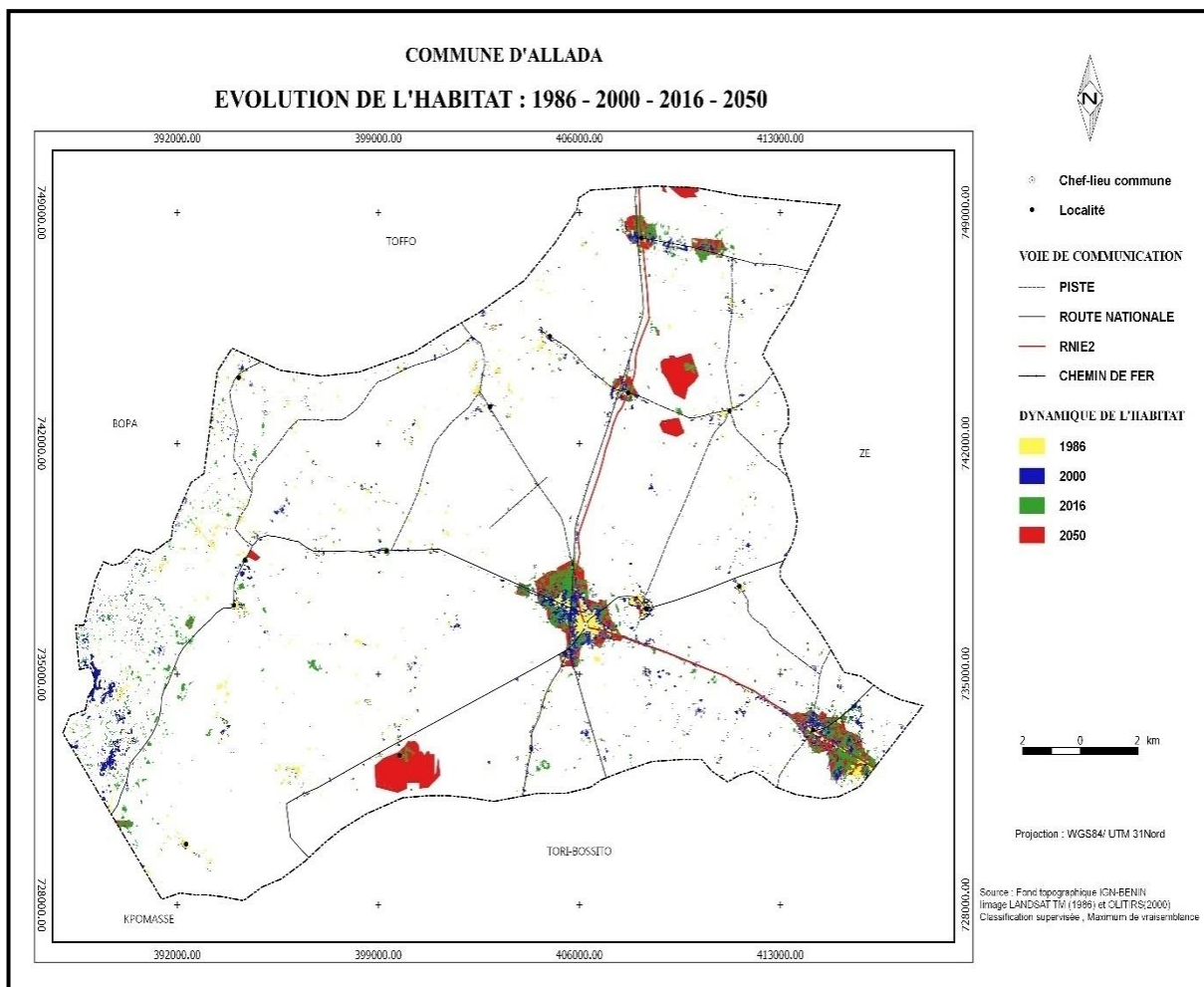


Figure-8: Priority areas to be developed by 2050.

Conclusion

This study made it possible to appreciate the organization of the different units of occupation of the soil. The different changes were observed thanks to the Landsat images of different dates. After a series of treatments, the GIS tools allowed for a comparative analysis of the land use over a period of thirty years. This analysis shows a regression of vegetation in favor of fields and agglomerations. In view of these results, we were interested in the different units of occupation but in particular in the agglomerations. A 34-year prospective analysis was done. From this survey, it appears that there is a concentration of the population, in spite of its demographic evolution, that the occupation of the consolidated zones is very slow, and that five boroughs will be priority arranged by 2050. It thus appears that there is concentration and not spreading, so instead of the authorities initiating several consolidation operations at once, they must make the previously consolidated areas viable and develop the agricultural areas. Land management is a major issue and its organization is essential for the economic development of agricultural areas such as the Commune of Allada. The municipality of Allada "must be a modern,

prosperous, united, cohesive and well-governed commune whose potential is mobilized and converged to improve the living conditions of local people and where the environment is Safeguarded and protected (MPCD, 2011) according to its vision of development⁷.

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