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Research Article

ANALYSIS OF THE SPATIO-TEMPORAL DYNAMICS OF SOIL OCCUPANCY AND LAND PROBLEMS IN THE IFANGNI TOWNSHIP

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A B S T R A C T

The Ifangni Commune suffered from strong anthropogenic pressure between 1995 and 2015 and as a consequence, there are serious land problems. Thus, the general objective of the study is to contribute to a better knowledge of gender issues related to primary school enrolment, in order to help Counterpart International and its partners, in particular, the Ministry of Education to better orient and target their actions for an effective fight against these gender-based inequalities in current and future programs. The analysis of the dynamics of occupation of the ground after the processing of LANDSAT image processing and the use of the ISIO model(Impact State Impact and Outcome) have established the relationships between the spatial dynamics and land issues in the Ifangni Township. As for the modeling of land use dynamics, it is done using the SpaCelle model where evolutionary trends in land use units by 2035 have been obtained. Modeling of land-use dynamics shows that between 1995 and 2015, declining categories concern dense plant formations, especially gallery forests and clear forests as well as savanna woodland. The ones that have evolved are the field mosaics and fallows. Projections made towards the 2035 horizon reveal that in the future, while agglomerations, fields and fallows will extend, open forests and savanna woodlands, as well as forests galleries and savannas with agricultural influence will be in net regression. It is important that the municipal authorities define the perimeters of protection of periurban agricultural and natural areas and areas to be urbanized. Similarly, fallow times must be rigorously revised upwards.

INTRODUCTION

In the nineteenth century, most cities of Africa were remarkably distinguished by their speed of spatial and demographic growth between which Vennetier, (1988) establishes a cause-and-effect relationship. For Canel *and al.,* (1990),this century has been for the African continent, the era of urban growth with relatively comparable rates for all countries. Benin, one of the West African countries, has not remained on the sidelines of this phenomenon of explosion and urban expansion (N'Bessa, 1999). Indeed, population growth puts pressure on natural resources in general and on urban lands in particular. The perception of the land that once was a collective and inalienable asset, changes with the gradual disappearance of customary law and the emergence of the notion of private property. So we must ask ourselves the question of what are the same environmental and land realities in the secondary cities of Benin, early growth, facing the continued occupation of men, in the face of growing needs grassroots populations and the development ambitions of local elected representatives and the requirements of sustainable development (WB, 2001) in the perspective of a successful spatial orientation. In Benin, the increase in population is followed by an increase in the demand for residential land and for agricultural activities. According to provisional results of the GCPH(General Census of Population and Housing)4, Benin's population has increased over the last ten years over the period 2002-2013 (3.5%) compared to the period 1992-2002 (3.23%), (INSAE , 2015). This demographic growth is at the origin of urbanization, whose infrastructure planning has not been able to keep up with the pace of development of today's cities. Conscious of this stake, the municipality of Ifangni leads since then, various actions in the field of land and urbanization. But this management leaves something to be desired against the current face of the city. The present study aims to better understand the land management methods in this locality to better control its urbanization through an analysis model.

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Background and Rationale

The world has experienced unprecedented urbanization in recent years. This phenomenon is accentuated in developing countries with an urban growth rate of 4% in Africa that exceeds that of Asia and Latin America (http: www.unhabitat.org). According to the same source, Africa's urban population grew from 15% in 1960 to 35% in 2006 and is expected to exceed 60% by 2030. An African Development Bank study carried out in 2004 on the transformation of settlements shows that the population of the West African sub-region has increased from eighty-seven million to four hundred and thirty million inhabitants, or about five (05) times between 1960 and 2002. From the same source, the urban population of West Africa, from twelve million (14% of the total population) in 1960 to seventy-seven million (or 40% of the total population) in 1990 more than six (06) times in 30 years. Estimates predict that 63% of the West African population would live in cities by 2020, more than one in two people. Benin is not on the sidelines of this trend. Urbanization has increased considerably in recent decades (N'Bessa, 1999). The four (4) population censuses of 1979, 1992, 2002 and 2013 show increasing urbanization with rates of 26.5%; 35.9%; 42% and 49.3%. Southern Benin alone accounts for more than half of the population (INSAE, 2015). The basic reasons for this rapid urbanization of Benin's metropolis in general are the permanent search for well-being, which translates into the displacement of rural people to cities in search of remunerative work (Vénnétier, 1988). But this rampant urbanization generates significant environmental problems, insecurity, lack of essential basic services (schools, health centers, drinking water, etc.) and increased poverty faced by municipalities. The housing problem also arises more and more in these metropolises of Benin and this has for corollary the surge of the price of the urban and peripheral residential areas. Spatial planning has become, with the declaration of the national spatial planning policy and the requirements of sustainable development (nature protection), a priority in the management of different types of human establishments. This translates into the realization of the Schemes and Master Plans of National or Communal Development, and the imposition of the Study ofEnvironmental impact (SEI) to different development projects such as the definition of the 1998 framework law (Dossou, 2009). Land management is not a static data. It evokes points of convergence and divergence of interests and evolves according to the priority values of a society or those imposed on it. Despite the various studies carried out on the environmental and spatial question, the questions of dynamics have not yet been analyzed in detail in the Ifangni Township. In the center of the country, however, the dynamic aspects of the occupation of space need to be known for the sustainable management of natural resources. It is also one of the interests that justifies the importance of this study in the Ifangni Township where forest formations and other natural components are threatened by human occupation. As an agricultural and cross-border Township, the Ifangni Township is today experiencing a demographic extension. The habitat of men today dominates its landscape and threatens the survival of urban or periurban agriculture in the Ifangni Township. This poses land problems. In addition to the reasons that have just been mentioned, the requirements of decentralization have mainly made land, the first communal resource currently much sought by the population and the local power of the city of Ifangni. The pressure on the latter is becoming stronger every day following the entry into the game of private actors who are already a medium and long term financial stake projected given the current level of development of the Township and these various assets. Spatial dynamics deserve to be known, evaluated and mastered in time through these different mechanisms, since it is from here that the great land problems experienced in the cities of southern and central Benin (Ousséni, 2005). The aim here is to make a two-way assessment, which can show the difficulties and advantages associated with this exploitation from a model, with the aim of a rational management of reserves and the currencies it yields. These observations raise three essential questions:

- What are the types of land use in the Ifangni Township and what are the explanatory factors for the observed mutations?
- What are the evolutionary trends in the dynamics of land use in the Ifangni Township?
- What are the measures required in view of current land and environmental problems in the direction of sustainable and rational management of the environment and urban space in Ifangni?

The main objective of the study is to contribute to a better knowledge of the land and environmental problems related to the dynamics of land use in the Ifangni Township.

It is specifically about:

- to analyze the spatio-temporal dynamics of land use between 1995 and 2015 in the Ifangni Township;
- to identify the different environmental and land problems caused by changes in land use;
- propose measures adapted to the observed changes while considering the sustainable management of the land in the Ifangni Township.

Presentation of the study area

The Ifangni Township is located in the southeast of Benin in the plateau department between 6 ° 32'00 " and 6 ° 44'00 " north latitude and between 2 ° 39'40 " and 2 ° 46 ' 40 " East longitude. Covering an area of 242 km^{2}representing 0.21% of the national area surface, the Ifangni Township is one of the common law communes of the Republic of Benin. It has 32 administrative villages and 08 city districts in six districts namely: Ifangni-Center, Banigbe, Lagbe, Daagbe, Chad and Ko-Koumolou. Figure 1 shows the geographical location of the Ifangni Township.

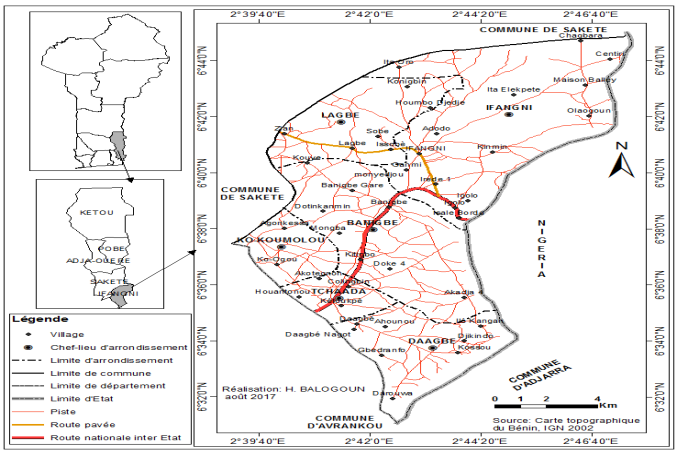

Figure 1 Geographic and administrative situation of the Ifangni Township

METHODOLOGICAL APPROACH

The method used derives from a transversal approach that is both analytical and diachronic. This method includes the following elements: data collection, desk research, processing and cartographic analysis, and modeling. The following documents were consulted:

- The maps developed by the National Geographical Institute (IGN) and by the Inland Consortium covering, among other things, the hydrographic network and human settlements;
- Topographic maps to 1/200000 published by IGN France, namely the Porto-Novo leaves (NB-31-XXI) which were used for the development of a topographical background;
- the South Benin land-use vector database, developed by CENATEL on the basis of Landsat TM images of December 1995;
- Benin's land-use vector database, developed by the IMPETUS project based on 2005-2006 Landsat ETM + imagery.

Given the problematic of the study, the sample size was determined by the Schwartz formula (1995) which is as follows:

$$n = \frac{Z\alpha^2 \times pq}{i^2}$$

together with:

n Sample size
$Z\alpha^2$ t = confidence level to 95% (typical value 1.96)
i = error margin at 5% (standard value of 0.05) which gives the desired precision or the confidence interval;
p = is the proportion of the population meeting the criteria set and q = 1 - p with $p = \frac{n}{N}$ with: n the number of heads of households in all the boroughs;

N : the total number of heads of households in the Ifangni Township (N).

Table I shows the distribution of households surveyed during the fieldwork.

Table I Distribution of households surveyed

Township	Districts	Number of households	Number of surveyed people
Ifangni	Ifangni	5964	73
	Daagbé	2892	42
	Tchaada	2261	34
	Ko-Koumolou	2635	39
	Banigbé	4848	63
	Lagbé	2762	41
	Total	21362	292

The characteristics of the used images are presented in Table II.

Table II Characteristics of the used satellite images

N°	Path / Row	Acquisition date	Sensor	Producer	Format
1	192/055	13/12	TM	USGS	GeoTIFF
2	192/055	01/2005	ETM +	USGS	GeoTIFF
03	192/053	(10/10)	OLI-TIR	USGS	GeoTIFF

Source: http://glovis.usgs.gov/

Classification evaluation: Kappa index

The Kappa index evaluates the agreement between the simulation results and the actual situation in the confusion matrix. It ranges from 0 to 1 and is divided into five categories (Table III).

Table III Degree of agreement and value of Kappa

Accord	kappa number
Very weak accord	[0 - 0.20]
Weak accord	[0.21-0.40]
Moderate accord	[0.41 - 0.60]
Substantial accord	[0.61 - 0.80]
Almost perfect accord	[0.81 - 1]

***Source**: Pontius and Millones, 2008*

The Kappa index provides information on the concordance between the data to be classified and the reference data (Congalton, 1991).

Statistical analysis of changes in land use status

The average annual rate of spatial expansion expresses the proportion of each unit of natural vegetation that changes annually. This annual rate Ta is calculated using the following formula (Bernier, 1992):

$$T_a = \frac{S1 + S2}{S1 \times (t2 - t1)} \times 100$$

With *S1* the area of a unit of occupation on the date *t1*, *S2* the area of the same unit of occupancy on the date *t2* and *t* the number of years between *t1* and *t2*.

Processing and statistical analysis of socio-economic data

The collected data were entered into the Excel table and used to generate the illustration graphs and summary tables.

The response rate (Tr) of the variables selected was calculated by category of actors or by category, inspired by the formula of Seastrom (2001).

$$T_r = \frac{n_i}{n} \times 100$$

n_i : Number of respondents who provided a response to a variable i;

not : total number of respondents.

At the actual analysis phase of the work, the results from the various treatments are used. Here, the diachronic type of analysis is used to better appreciate the evolution of the identified land-use units. In order to identify, group and establish logical relationships between the different parameters used in the spatial dynamics of the Ifangni Township, a second method of analysis is included in the concept of the PEIR model (Pressure , Status, Impact and Response) is also used. Figure 2 shows an example of the PEIR model.

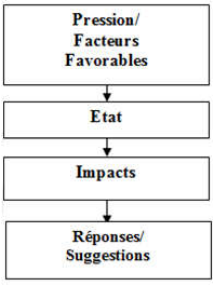

Figure 2 PEIR Conceptual Model

RESULTS AND DISCUSSIONS

Results

State of land use in 1995, 2005 and 2015

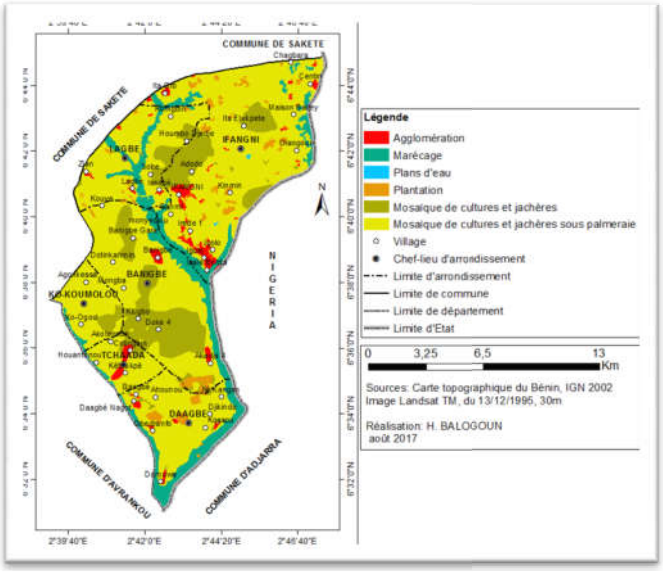

Figure 3 Units of occupation of the soil in the Ifangni Township in 1995

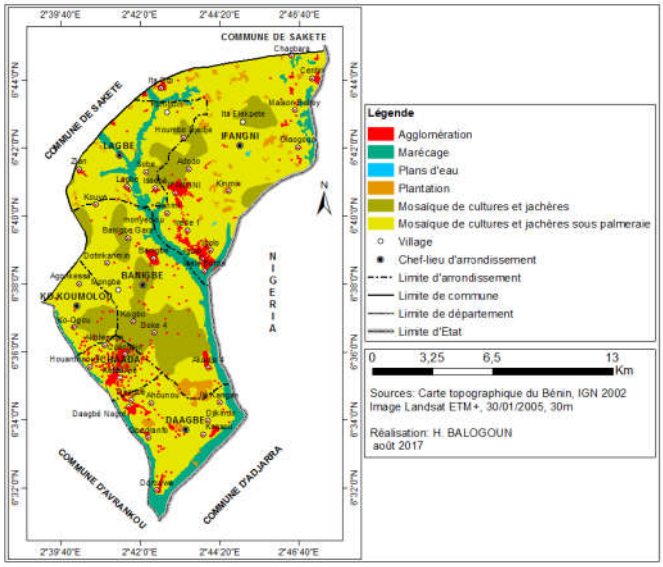

Figure 4 Land use units in the Ifangni Township in 2005

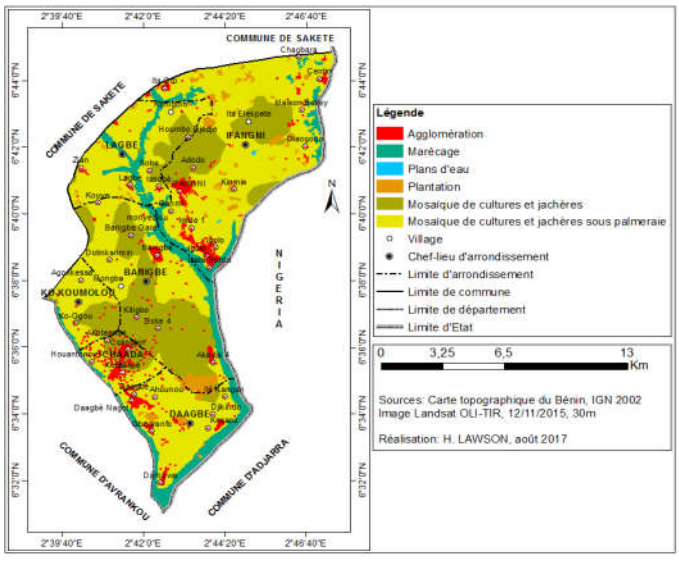

Figure 5 Units of land occupation in the Ifangni Township in 2015

Table IV Transition Matrix of Units of Land Occupancy from 1995 to 2005

Units 2005 / Units 1995	AG	MG	MCJ	MCJP	PE	PL	Total 1995
AG	510.74	0	15.12	25,45	0	0	551.31
MG	0	2012.45	78.39	52,78	0	37,94	2181.56
MCJ	45.54	0	2600.85	207.36	2.21	6.9	2862.86
MCJP	59.12	1.25	483.81	12354.82	0	144.47	13043.47
PE	0	0	0	2.6	4.88	0	7.48
PL	0	2.84	11.4	138.38	0	371.41	524.03
Total 2005	615.4	2016.54	3189.57	12781.39	7.09	560.72	19170.71

Legend: AG: Agglomeration; MG: Swamp; MCJ: mosaics of fields and fallows, MCJP: mosaics of fields and fallows under palm plantation; PE: Body of water; PL: Planting

Figure 6 shows the evolution of the units of land occupation between 1995 and 2005

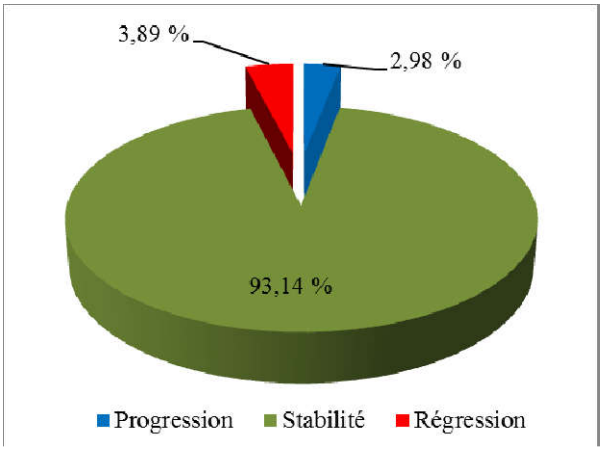

Figure 6 Evolution report of units of land use between 1995 and 2005

Table IV Transition Matrix of Units of Land Occupancy from 2005 to 2015

Units 2005 / Units 1995	AG	MG	MCJ	MCJP	PE	PL	Total 2005
AG	608.45	0	6.15	0.8	0	0	615.4
MG	36.59	1969.62	1.45	5.51	0.63	2.74	2016.54
MCJ	15.79	0	2918.91	10.25	0.25	244.37	3189.57
MCJP	2.78	0.03	1759.58	10978.45	0.93	39.66	12781.43
PE	0	0.25	0.05	0	5.28	1.51	7.09
PL	0.38	41.43	11.25	163.5	0	344.12	560.68
Total 2015	663.99	2011.33	4697.39	11158.51	7.09	632.4	19170.71

Figure 7 shows the evolution report in units of land use between 2005 and 2015

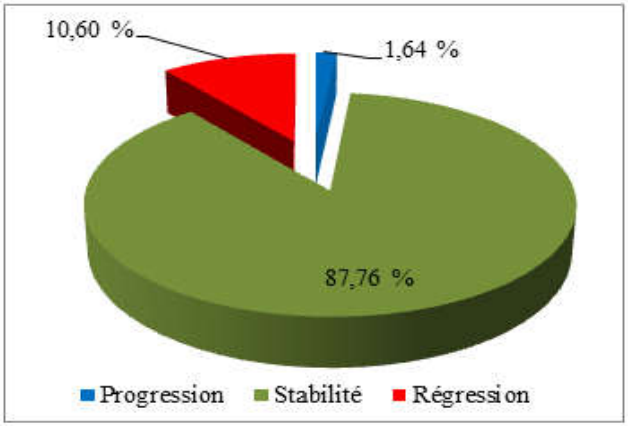

Figure 7 Evolution report of the units of occupation of the soil between 2005 and 2015

Table IV Transition Matrix of Units of Land Occupancy from 1995 to 2015

Units 2005 / Units 1995	AG	MG	MCJ	MCJP	PE	PL	Total 1995
AG	541.45	0	8.74	1.12	0	0	551.31
MG	29,59	2002.03	101.04	45.98	0.58	2.34	2181.56
MCJ	69.45	0	2548.25	14.58	0.21	230.3	2862.79
MCJP	290,214	0.05	2027.58	10933.33	1.74	75.83	13043.51
PE	0	0.23	0.05	0	4.56	2.21	7.05
PL	18.52	9.02	11.73	163.5	0	321.72	524.49
Total 2015	663.99	2011.33	4697.39	11158.51	7.09	632.4	19170.71

In sum, for this period, the analysis of Figure 8 allowed to assess the landscape dynamics, firstly by regression (12.18%), and secondly by class stability (85.29% of the landscape).

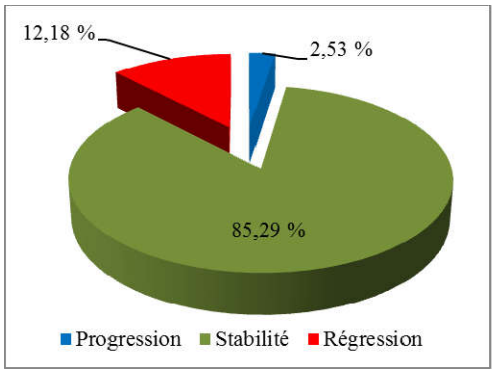

Figure 8 Evolution report in units of land use between 1995 and 2015

Figure 9 illustrates the overall evolution of the areas of the different units of occupation of the Ifangni Township during the analysis period.

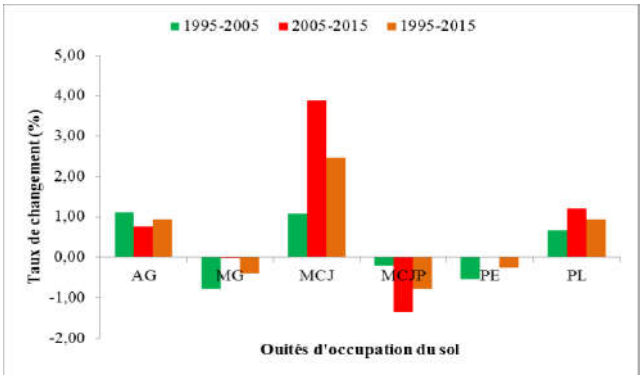

Figure 9 Change in area of land occupation class from 1995 to 2015

Land issues related to the dynamics of units of land use in the Ifangni Township

Figure 10 shows the different modes of access to land in the Ifangni Township.

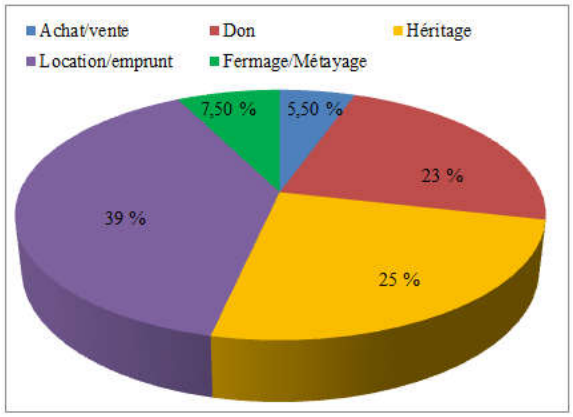

Figure 10 Modes of access or acquisition of land

Land issues

The land pressure is reflected in the Township at the scale of the territory of the districts of Tchaada and Ifangni, with the development of constructions (photos 1 and 2), by a gradual change of both land use patterns and agricultural and rural activity.

Photo 1

Photo 2

Photo 1 shows that a subdivision operation on the ground creates an organization in the form of rectangular islands in terms of housing and structuring of the building. Thus, the spread of subdivision projects ensures, as a result, a certain continuity of urban buildings on their periphery.

In photo 2, there is a notice of destruction of a building in the application of the plan of subdivision of the district of Tchaada. In their implementation, subdivisions also involve partial or total destruction of establishment. In Benin's current practice, the owners of these constructions do not claim compensation for the damage caused considering that it is the price to pay for the land regulation.

A- Two plates indicating different owners planted on the same plot (Igolo district).
B- Installation of a litigation identification plate on a non-built site in the Irede district.

Evolution of units of land occupation by 2035

The SpaCelle cellular automaton has made it possible to calculate future dynamics (2015-2035) based on observations of past evolutions (1995-2015) and their probability (Figure 11).

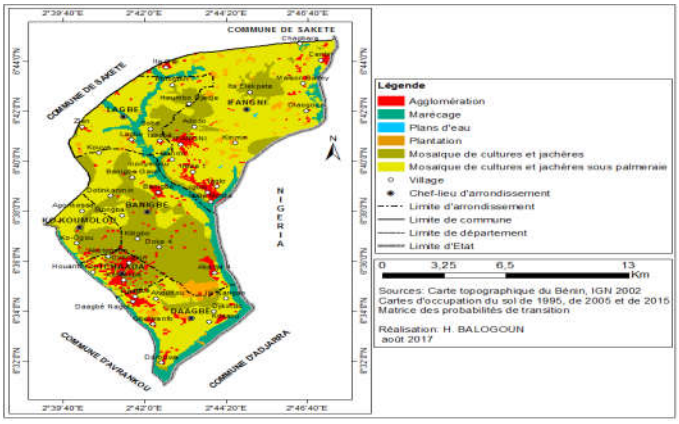

Figure 11 Predictive map of units of land occupation in the Ifangni Township by 2035

The objective of this modeling is not to predict a future situation but to stimulate the reflection on the planning of a dynamic territory. These tools, if they complement traditional planning methods and if they accompany a more qualitative type of prospective reflection, intensify exchanges, can lead to the co-construction of hypotheses and enrich the knowledge produced by the specialists of questions of territory development.

Figure 12 presents the pressures, the state, the impacts and the responses that are exerted on the spatial dynamics and the land in the Ifangni Township.

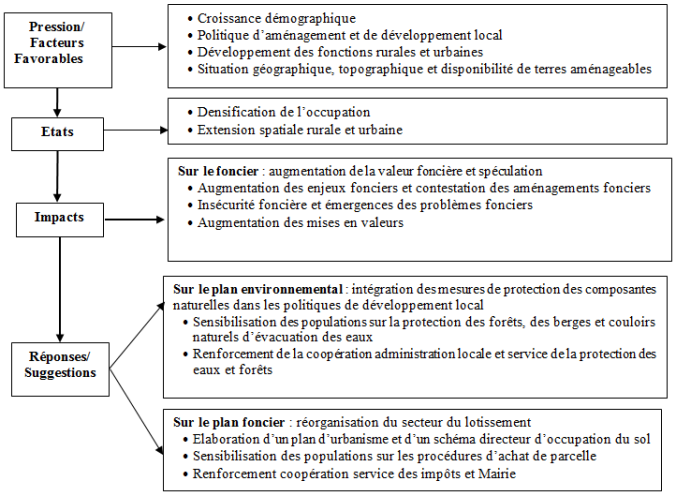

Figure 12 Model of land use analysis in relation to spatial dynamics and land in the Ifangni Township

In short, demographic dynamics is an inseparable phenomenon of the land question given the existence of the cause-and-effect relationship between them.

DISCUSSION

The SpaCelle model estimates, from the layers of land occupation, the rules of life, the transition rules and the quantities of future changes from a probabilistic (random) method. Thus, between 2015 and 2035, the model found a regression (-0.31) of mosaics of fields and fallow land under palm groves , which from an environmental point of view is possible in Benin. This could be explained by the fact that palm groves are destroyed at the expense of fields (FOSA-Benin, 2001). However, this decline in palm groves could be attributed to recurrent vegetation fires and the excessive exploitation of palm wine in the Plateau department. It can therefore be deduced that palm groves in the commune do not benefit from good conservation. From a technical point of view, the SpaCelle model predicts the state of the cells to be simulated for a future period based on the initial state and the strength of the surrounding cells. In other words, this model simulates the "landscape pattern", not the processes that produce them. In terms of land, the results show that, due to the favorable natural and socio-economic conditions, the area of agglomerations in the Township has expanded considerably. Thus, from 551.31 hectare in 1995, agglomerations reached 663.99 hectare in 2015 and will increase to 944.78 hectare in 2035. This spatial growth induces land tenure difficulties (reduction of the size, increase of the sale prices of the plots, conflicts between actors, etc.) without forgetting the environmental disappointments (destruction of the vegetal cover, sanitation problems, etc.). The definition of an ambitious urban policy deserves to be made in order to ensure the sustainable development of this city. The upsurge in land issues and their impacts in the Ifangni Township are the result of population growth following the agrarian change. To these demographic factors are added socio-economic and political factors related to agriculture, socio-economic influence, State policy in the management of natural resources, and so on.

CONCLUSION

Located in the Plateau Department, the Ifangni Township presents favorable conditions for the development of agricultural activities. The availability of agricultural land, vegetation combined with population growth, are factors that made possible changes in the different units of land use. This influenced land practices in the Township. The treatment of land-use units in their present and past state using remote sensing and SIG techniques reveals an upward trend in cultivated areas to the detriment of wetlands and palm groves. Modeling of land-use dynamics, using transition matrices and probabilities, shows that most other land-use categories lose considerable area to fields and fallows, with conversion rate well above 50% between 2005 and 2015. According to predictive modeling, this trend will continue towards the 2035 horizon. Such a situation results in reduced fallow time, overexploitation of agricultural land, reduced soil fertility and, as a result, reduced agricultural yield. These consequences are perceptible by farmers and some are forced to rush on the ecosystems of the lowlands. It is clear that the dynamics affecting interfluves have an impact on the lowlands. The mentioned trend will also affect these lowlands as the density of the population increases. Given the extent of rural migration in the study area, hence the interest for state and local authorities to think about safeguarding interfluves and a consequent development plan for hydromorphic areas such as the lowlands. Finally, the assessment of the impacts of land use dynamics on land could be carried out across the Plateau Department. This will allow the implementation of national policies aimed at reversing the perilous trend of deforestation, to the benefit of both populations and the overall environmental balance.

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