Analysis of the effects of climate and anthropogenic pressures on land cover/ land use in the lower valley of Ouémé

Charles C. HOUNTON, Attanda Mouinou IGUE, Claude CODJIA, Georges AGBAHUNGBA

Abstract— This study aims to analyze the factors that influence the changes in land use in the Lower Valley of Oueme based on remote sensing and population data.

The methodology is based on change detection in land cover using a series of satellite images of 30m of resolution between 1986 and 2015. These data are combined with demographic and climate data.

The results validated by global accuracy (97% for TM in 1986 and 98% for Oli 2015) and Kappa index (97% for 1986 and 97.69% in 2015) have shown that between 1986 and 2015, the part of anthropic land gradually spread to the detriment of natural cover in the Lower Valley of Oueme. The study also showed that land degradation is correlated with the evolution of the population and the expansion of social and community infrastructure. The effects of climate variability and land pressure also are factors very instrumental in these changes.

.**Index Terms**— anthropogenic pressures, climate, land use, remote sensing, Lower Valley.

1 INTRODUCTION

The dynamics of the degradation of the rural environment already begun by human action is accelerated by climatic conditions that are increasingly unfavorable [12]. The Lower Valley of the Ouémé river belongs to the great Valley of the Ouémé. It is recognized to be one of the richest valleys in the world for its immense agricultural potential which, unfortunately, is not yet fully exploited [14]. This wetland is an ecosystem of strategic and scientific interest because of its ecological, economic and sometimes cultural role [18].

The region is under many pressures of all kind on its resources. Reinforced by strong population growth, these pressures are also climatic and this valley then presents itself as a large flood zone where the hydrographic system remains very complex [6].

This work aims to analyze the factors that influence changes in land cover/ land use in the Lower valley of Ouémé in order to contribute to the sustainable management of natural resources.

The Lower Valley of Ouémé (BVO) is located in the South-East region of Benin between 6 ° 35'21 '' and 6 ° 53'66 '' north latitude and between 2 ° 21'26 '' and 2 ° 28'01 '' east longitude (Figure1).

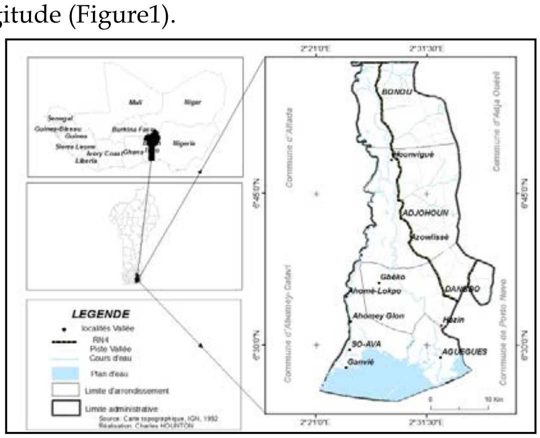

Figure 1: Situation of the Lower Valley of Ouémé

The Ouémé river is the main river whose hydrological regime is marked by significant variations during the year [16]. It is a region that experiences an equatorial transitional or Equatorial-Guinean climate with two rainy seasons and two dry seasons [29]. The natural vegetation of the Ouémé valley, like most parts of southern Benin, has been severely degraded. It is a zone of great diversity of fauna.

2 DATA AND METHODS

2.1 Review Stage

The data used in this study are:
- Four landsat images of 1986 (TM) and 2015 (OLI). These orthorectified and georeferenced images were chosen during the dry seasons in January with cloud cover from 0% to 10% and projected in the UTM system WGS84, zone 31N.
- devices such as GPS receiver to take waypoints,
- ENVI 5.1 software for the pre-processing and processing of landsat images,
- ArcGIS Desktop 10.2.1 for GIS applications and map development.
- cartographic documents, agricultural statistics (from CARDER), climatic data (from ASECNA), and demographic data (from INSAE).

2.2 Methods

The satellite image classification method consisted of pre-processing, classification and post classification. Pretreatment involves atmospheric and radiometric correction.

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The pretreated image was enhanced and then subjected to different colored compositions to facilitate visual interpretation in order to define the training areas. The result obtained was finally classified by maximum likelihood to give maps of land use of 1986 and 2015.

The processing of demographic data and agricultural statistics was done with the Excel software. These data were first entered and then grouped by data type. Each type of data has been represented graphically to show its evolution in 1986 and 2015.

–Calculation of some statistical parameters

✓ The arithmetic mean.

It is a positional parameter. Let mx be the mean. It is expressed as follows:

$$m_x = \frac{1}{N}\sum_{i=1}^{n} x_i \qquad (1)$$

✓ Variance and standard deviation

These are dispersion parameters. The variance of the population is defined by the formula:

$$S_x^2 = \frac{1}{N}\sum_{i=1}^{n}(x_i - m_x)^2 \qquad (2)$$

Let Sx be the standard deviation of the population and σ be the deviation of the sample.

It is conceivable that if N tends to infinity, σ^2 tends toS^2_x. But if for a given N, we perform this calculation for a large number of samples, we will find that the average of σ^2 is generally less than S^2_x.σ^2 is therefore a convergent estimator of Sx but it is biased . It is then interesting to dismiss it. Hence by knowing $\bar{x}$ or mx, we have:

$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{n}(x_i - m_x)^2 \qquad (3)$$

❖ The coefficient of variation

It is an index which allows to characterize the spatial variability of the fields of a given random variable (rain, flow, etc.). It is defined as the ratio of the standard deviation of the series to the mean:

$$C_V = \frac{\sigma}{m} \qquad (4)$$

❖ Rainfall indices (SPI) and hydrometric indices (SDI)

✓ Calculation of IPS and SDI

The rainfall and hydrometric indices are used to identify the main trends in the time series and to better visualize the periods of deficit and surplus at the annual scale. These indices were centered and reduced from the formula below:

$$Vcr = (P - P_{moy})/\sigma \qquad (5)$$

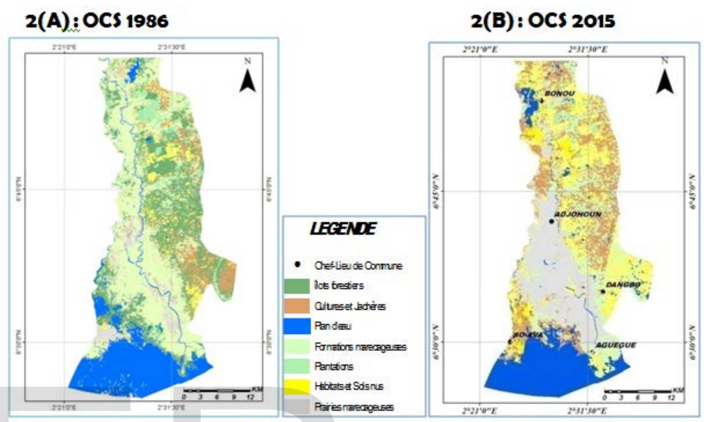
Where Vcr is the reduced centered variable (raifall index (SPI) or hydrometric index (SDI) according to the given variable), P is the cumulative variable over a given period, P_{moy} is the mean of the time series over the period of study and σ is Standard deviation of the series over the period of study [11].

3 Results and Discussion

3.1. Results

3.1.1. State of land cover in 1986 and 2015.

The characteristics of the land use map of1986 (Figures 2A and 3) showed the following trends: predominance of crops

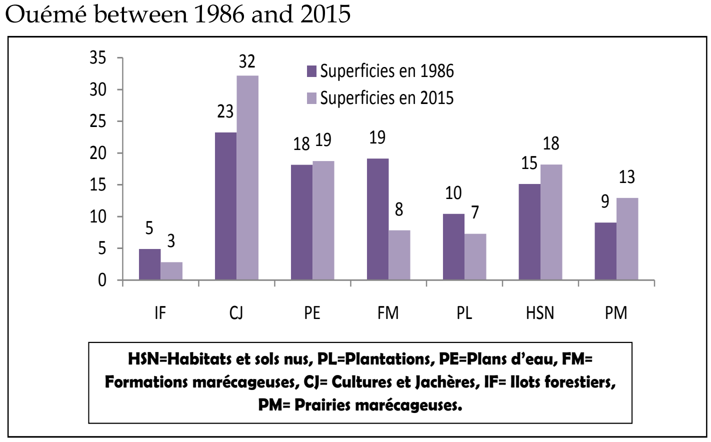


and fallow land (23%), marshes with 19%, water bodies (18%), habitats and bare soils (15%), plantations occupied 10% of the total area. Less dominant units are swamp grasslands for 9% and isolated forests for 5%.

Figures 2 (A): 2 (B) : Land use maps of the Lower Ouémé valley in 1986 and 2015

For the year 2015 (Figures 2B and 3), crops and fallow land increased significantly to 32 per cent, habitats and soils bare (18 per cent), and swamp grasslands (13 per cent). As for the water bodies, they maintained relative stability around 19% of the total area of the Lower Ouémé valley, whereas the marshes, plantations and isolated forest have deteriorated considerably and represent only respectively 8%, 7% and 3% of the extent of the Lower Ouémé Valley.

Figure 3 : Evolution of land use in the Lower Valley of Ouémé between 1986 and 2015



(Source: landsat Images, 1986).

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3.1.2. Confusion matrix of land cover in 1986 and 2015

The analysis of the different confusion matrices showed an overall precisions set in tables II and III.

Using maximum likelihood classification method, the overall accuracies were of 97% and 98% for the classification of the TM images of 1986 and the ETM of 2015respectively.

Table I: Confusion matrix for the classification of Landsat TM image of 1986

Source: Landsat TM image (1986) classification and field data

The Kappa coefficients are respectively 97% for 1986 and 97.69% for 2015. These different rates reflect the quality of the classification. These criteria also indicate a very good classification result.

Table II: Confusion matrix for the classification of the landsat OLI image of 2015

Classes	HSN	PL	PE	FM	CJ	IF	PM	EC	PU
HSN	99	3	0	0	1	0	0	3.88	96.12
PL	0	93	0	6	1	0	0	7	101
PE	0	0	10	0	0	0	0	0	100
FM	0	3	0	93	0	0	0	3.13	96.88
CJ	1	0	0	1	97	0	0	2.02	101.0
IF	0	1	0	0	0	99	2	1.01	103.0
PM	0	0	0	0	1	1	98	3.88	96.12
EO	1	7	0	7	3	2	1	20.92	
PP	99	93	10	93	97	98	99		97 %

Source: Landsat OLI image (2015) classification and field data

❖ The Transition Matrix between 1986 and 2015.

Table III: Transition Matrix from1986 to 2015

The transition matrix	IF	CJ	PE	FM	PL	HSN	PM	Total
IF	32.0	20.0	3.34	7.96	30.0	5.67	1.3	100
CJ	0.53	36.7	0.96	22.9	6.83	23.3	8.7	100
PE	0.00	0.00	97.0	1.00	0.00	0.00	2.0	100
FM	0.03	9.42	0.32	63.8	1.55	17.9	6.9	100
PL	1.00	13.6	0.12	2.00	74.0	1.92	7.1	100
HSN	0.08	1.00	0.66	0.30	3.78	89.0	5.0	100
PM	7.58	7.18	2.21	2.00	0.09	23.0	58.	100

Source: Landsat TM Images1986 and 2015classification and field data

3.1.2. Factors of Change

❖ Anthropogenic factors of changes in land cover and land use

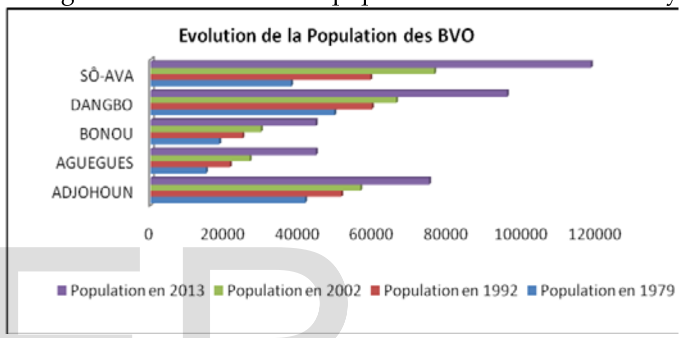
Man is ahead in land cover and land use changes, as he controls most of land surfaces. Between one third and one half of land surfaces have been transformed by man [17].

- Evolution of the population of the Lower Valley of Oueme

The population of the Lower Valley of Ouémé has increased in time and space (Figure 4). In fact, the Lower Valley of the Ouémé river sheltered a population of 162.195 inhabitants in 1979. This population evolved quantitatively and will reach 378.275 in habitants in 2013 It has therefore increased from simple to double in 30 years [15].

With the exception of the municipality of Sô-Ava, which has seen its population tripled from 37818 in 1979 to 118497 in 2013, the other communes of the Lower valley of Ouémé have seen their population doubled over the last thirty years.

Figure 4: Evolution of the population of the Lower valley



of Ouémé from 1979 to 2013

As it is known that more than 90% of this population is mainly agricultural **[30]** and the level of urbanization of the region is growing up, it is normal to consequently suffer a fairly high rate of degradation.

- **Evolution of agricultural areas.**

The increase in the population of the Lower Valley of Ouémé evolves concomitantly with the cultivated areas. Figure 5 shows the evolution of the agricultural areas of the Lower Valley of Ouémé. The area of corn is clearly increasing, while relative stability in other crops is observed.

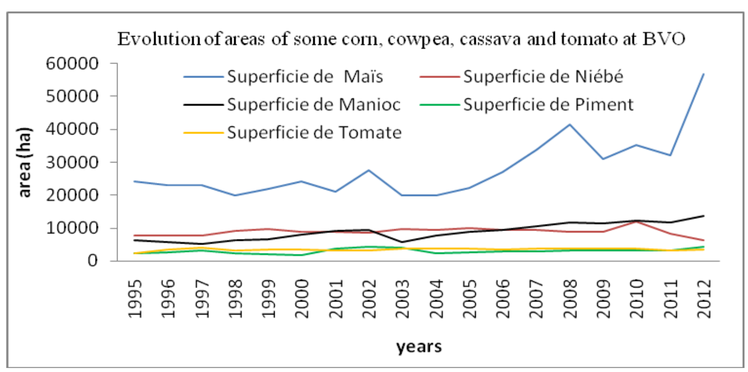


Figure 5: Evolution of the area of some crops in the BVO

- **Impact of transhumance**

In the Lower Valley, the transhumance is manifested by the crossing or the stay in large numbers of foreign herds in the terroirs of the communes.

The current management of transhumance does not allow to evaluate its numerical importance according to the origins of the animals. Figure 6 shows the origins of cattle in the BVO.

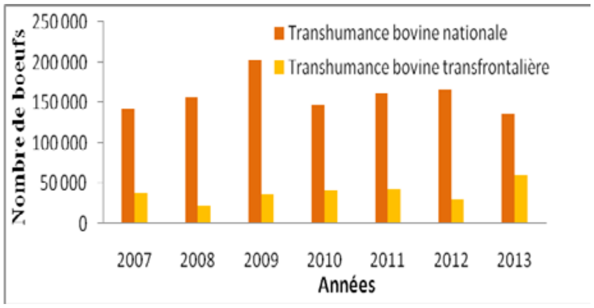


Figure 6: Comparative evolution of national and transboundary cattle transhumance

Source: Statistics from Directoration of Livestock / MAEP

According to Rachad *et al*. (2015) **[25]**, it is estimated that in 2013, out of 10,732 heads of cattle registered, about 8,732 entered the communal territory by the neighboring district of Kpedekpo (municipality of Zagnanado), it means 81% come from Nigeria, the rest , Or about 2,000 heads, comes in decreasing order of importance from northern Benin, Niger and Burkina Faso.

The grazing resources then available in the BVO are degraded by overgrazing, the cattle no longer allowing the regeneration of certain shoots and leaving either to strongly and totally denuded soils or to a new vegetation(non-consumable plants), to a proliferation of bushy and non-forage species and to an increase in annual, ephemeral species at the expense of natural regeneration.

Another detrimental effect of livestock is the trampling of soils. This prevents the regeneration of young shoots and causes the reactivation of certain soils previously protected from erosion by, for example, superficial crusts.

• Impacts of the construction of roads and land policy

The network of roads is a mean of organization and appropriation of space by the populations [21]. Roads are the structural factors in the dynamics of land tenure. At the level of the Lower Valley of Ouémé; the construction and asphalting of the Akpro-Missérété -Dangbo-Adjohoun-Bonou-Kpédékpo road started in 2007 is an illustration of this (Figure 7).

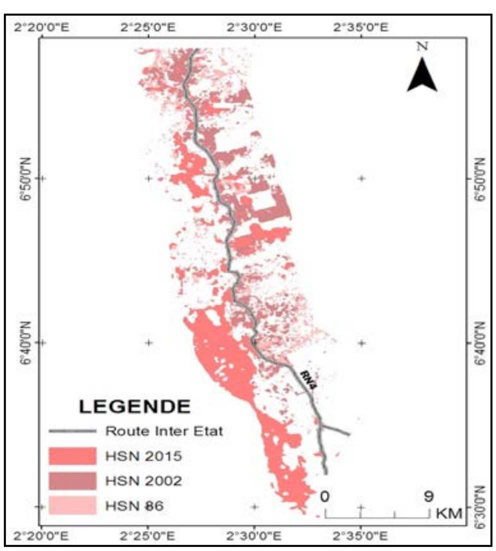


Figure 7: Mapping the evolution of habitats and bare soils at a distance of 5 km along the road network

At 5 km buffer, the rate of increase in urbanized areas between 1986 and 2015 was only 40.22%. The development of this infrastructure, coupled with the strong population growth, contributed to the expansion and densification of urban areas. Thus, the calculated harmonic mean gives an overall increase of 23.27% in the rate of urbanization between 1986 and 2015.

On the land level, the majority of farms in the Lower Valley of the Ouémé are family. The main ones are: personal property (63%); Family ownership (46%) and rental (14%). In 2013, according to the results of the AGVSA survey, between 35% and 62% of the BVO farmers were owners of the fields they grow; And between 46% and 64% worked on family properties. Between 15% and 40% of family farms grew on rented land.

❖ Climate factors

Climate variability, even in the context of a highly anthropized system such as an agricultural area, remains a determining factor in changes in land cover and use [8].

It can have an impact on agricultural yields through changes in vegetation cover [28].

• Rainfall indices

The yearly rainfall for each station was calculated over the period 1981-2011 (Table IV). The analysis of the spatio-temporal variability of the annual rainfall indices during the various decades from 1980 to 2011, allowed to situate the Lower Valley of the Ouémé in its spatio-temporal context.

Table IV: Statistical parameters of annual rainfall from 1981 to 2011

Stations	**Bohicon**	**Bonou**	**Adjohoun**	**Cotonou Aéroport**	**Porto-Novo**
Mean	1115,9	1197,5	1111,0	1305,5	1198,5
Minimum	679,4	742,3	743,8	799,8	627,7
Maximum	1540,2	1877	1553,4	2203,3	1745,6
Standard	199,9	261,5	227,1	350,8	269,4
median	1107,1	1204,9	1074,8	1241,1	1176,7
coef. Var	0,18	0,22	0,20	0,27	0,22

SOURCE: ASECNA DATA, 2015

For all stations, there wasa low yearly variability of rainfall. Moreover, the coefficients of variation indicated a low spatial variability of precipitation in this region. During the period 1981 to 2011, the Bonou station recorded the lowest cumulative value (1197.5 mm) while Cotonou had the highest (1305.5 mm).

The standardized precipitation index showed a situation dominated by a moderate drought for all rainfall stations except Bonou where moderate humidity predominated along 38.7% of the observation years (Table V).

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At the station of Bohicon, 38.7% of the years of observation experienced a moderate drought and 16.1% corresponded to a severe to extreme drought. During the same period, 38.7% of the years of observation suffered a moderate drought and 16.1% corresponded to a severe drought in Cotonou. At the same station, 45.1% corresponded to humidity with variable intensity, dominated with moderate humidity (29%). At the station of Adjohoun, the dominant climatic phenomena are always moderate drought (32.3%) and moderate humidity (29%).

Table V: Magnitude of drought (and humidity) rainfall between 1981 and 2011

Variable	Station	Gamme SPI	Interpretation	% d'années
Rain (1981-2011)	Cotonou-Aéroport	SPI>2	extreme Humidity	3,2
		1<SPI<2	High humidity	12,9
		0<SPI<1	Fairly humidity	29,0*
		(-1)<SPI<0	Fairly drought	38,7*
		(-2)<SPI≤(-1)	High drought	16,1
		SPI≤(-2)	Extreme drough	0
	Bohicon	SPI>2	extreme Humidity	3,2
		1<SPI<2	High humidity	16,1
		0<SPI<1	Fairly humidity	25,8*
		(-1)<SPI<0	Fairly drought	38,7*
		(-2)<SPI≤(-1)	High drought	12,9
		SPI≤(-2)	Extreme drough	3,2
	Bonou	SPI>2	extreme Humidity	6,5
		1<SPI<2	High humidity	6,5
		0<SPI<1	Fairly humidity	38,7*
		(-1)<SPI<0	Fairly drought	29,0*
		(-2)<SPI≤(-1)	High drought	19,4
		SPI≤(-2)	Extreme drough	0
	Adjohoun	SPI>2	extreme Humidity	0,0
		1<SPI<2	High humidity	19,4
		0<SPI<1	Fairly humidity	29,0*
		(-1)<SPI<0	Fairly drought	32,3*
		(-2)<SPI≤(-1)	High drought	19,4
		SPI≤(-2)	Extreme drough	0,0
	Porto-Novo	SPI>2	extreme Humidity	3,3
		1<SPI<2	High humidity	13,3
		0<SPI<1	Fairly humidity	30,0*
		(-1)<SPI<0	Fairly drought	43,3*
		(-2)<SPI≤(-1)	High drought	6,7
		SPI≤(-2)	Extreme drough	3,3

Source: ASECNA data, 2015

- **The temperatures**

Figures 8 and 9 show the evolution of average temperatures from 1981 to 2011 at the Cotonou and Bohicon stations.

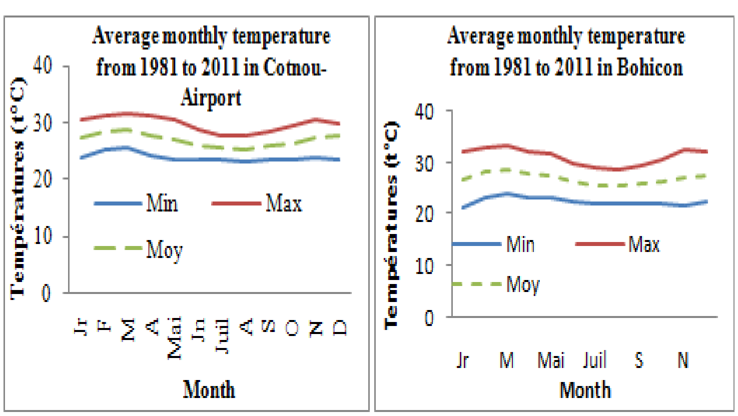

Figure 8 and 9: Temperature change Monthly averages from 1881 to 2011 in Cotonou.
Source: données ASECNA, 2015

As a result of the analysis of these graphs, average temperatures have undergone variability over the past three decades. There has been a considerable temperature rise over the last three decades, which would result in a fairly high degree of aridity in the area and, more partially, a depletion of the useful reserves.

3.2. Discussion

The maximum likelihood classification showed an overall accuracy of 97% for the TM image of 1986 and 98% for the image of 2015. The obtained Kappa were 97% for the TM image of 1986 and 97.69% for the image of 2015. Theses indices showed the validity of the maps from images classification. These results are confirmed by the work of Pontius (2000) [24] cited by Oloukoi et *al*. (2006) [22], which showed that a study of land use can be validated if the Kappa index is between 50% and 75%. According to Congalton (1994) [7], Chalifoux S. et *al.* (2006) [5], the validity of a classification requires an overall accuracy of 85%, the USGS proposes a minimum overall accuracy of 85% for Landsat imagery. Two important factors explain the changes in land use in the Lower Valley of Ouémé. If these changes are explained by anthropogenic actions, the same can be said for climatic variability on natural resources in general and plant formations in particular.

Human occupation is the primary cause and the most important factor of pressure on land. Indeed, man uses the land either for their dwelling or for their production. Agriculture, transhumance, infrastructure, land pressures degrade the natural ecosystems of the Lower Valley of Ouémé. An analysis of the dynamics of land use in the Lower Valley of Ouémé from 1986 to 2015 revealed an expansion of areas devoted to culture and urban spaces. The data collected and analyzed revealed a trend that showed an increase in agricultural areas (from 23% to 32%), agglomerations (habitats and bare soils: from 15% to 18%) to the detriment of other categories of farming, units of land use. Dense forests have undergone a highdecline (from 5% to 3%). Thus, isolated forests account for only 3% of the total area of the low Valley. These findings confirm those already observed by several scientists in the Upper basin of Ouémé. Indeed, Akiyo (2004) [2], Houndagba et *al.* (2007) [13] identified local and regional factors that explain the degradation status of Toui-Kilibo forest. These factors of pressure are associated with the collection of firewood and the manufacture of coal, especially for commercial purposes. This modification of the vegetation cover by clearing, cuts of timber and wood energy exposes the soils to the phenomena of run off and weakens them [14]. This dynamic is the consequence of the practice of slash-and-burn agriculture as the main cultural technique for decades on these soils [14]. For Ali (2010) [3], urbanization is also a factor of land degradation. It translates into an increasing demand in urban areas. Leroux L.(2012) [20], in his study at the upper

Ouémé basin identifies the creation of roads as a factor that would initially lead to major cuts in forests for their establishment and then, they are the starting point of deforestation for the cultivation of new areas. The Lower Valley of Ouémé has also become a corridor of transhumance. This transhumance corresponds, according to Abdelguerfi and Ramdane (2003) [1], to an overloading and a too long stay of the livestock on the paths translating by an annual levy of a quantity of forage units greater than the production of these routes. Overgrazing is therefore generally considered to be an essential cause of the degradation of natural ecosystems [4].

Climatic variability revealed that the climatic parameters studied in the lower valley of the Ouémé are very variable in time and space. Rainfall is declining from 1986 to 2015. This decline is associated with a warming through a rise in temperature. This trend remains a reality in the last 10 years with poor distribution of rainfall and increasingly frequent extreme cases. Houndagba et *al.* (2007) [13] have linked the degradation of vegetation cover to climate change, including the downward trend in rainfall totals since the drought of the 1970, and the effects of population movements and livestock are well known. Indeed, an isolated year of drought, even extreme may be less dramatic than a continuation of two years (or more) of moderate drought [10]. Ozer et *al.* (2005) [23] deduced that the main climatic constraint is not simply the scarcity of precipitation, but also the variability in its distribution, and the unpredictability of precipitation, which increases from south to north, and which constitutes control factors that determine the ecosystem and vegetation change. Water deficits according to FAO (1999) [9] have led to a decline in primary production, a change in the structure of the vegetation cover and a massive reduction in wildlife and livestock. These results corroborate those of the study of Soumaré et *al.*, (2009) [26] cited by Sogodogo A., (2015) [27] in the Loulouni region of Mali.

4 Conclusion

At the end of this study, it can be noted that climate and anthropogenic pressures are factors that influence the dynamics of land-use changes in the Lower Valley. Their identification and analysis, based on satellite and demographic data, revealed the extent of the phenomenon in order to help conserve the ecosystem and its biodiversity.

The study showed that the progressive occupation of the soil by human practices is one of the main causes of the degradation of the natural environment. It highlighted the effect of the climate, which is not negligible in this part of the country. It also highlighted the current patterns of natural resource use that do not meet sustainability standards. This is a concern for the conservation of the ecosystem.

To help conserve the ecosystem and its biodiversity, public awareness is needed. The definition of the national rural land security policy, the establishment of local agreements with regulatory mechanisms guaranteed by the local public authorities could be envisaged within the framework of the management of the space.

References

[1] Abdelguerfi A et Ramdane M. S. A., 2003. FEM /PNUD, Projet ALG/97/G31, Plan d'Action et Stratégie Nationale sur la Biodiversité, TOME VII, Evaluation des besoins en matière de renforcement des capacités nécessaires à l'évaluation et la réduction des risques menaçant les éléments de la diversité biologique en Algérie, bilans des expertises.157 p, 2003.

[2] Akiyo S. 2004. Contribution à l'évaluation de la mise en oeuvre du plan d'aménagement participatif des forêts classées de Tchaourou et Toui-Kilibo. Mémoire de maîtrise de géographie. DGAT/FLASH/UAC/Bénin. 112 p.

[3] Ali K. F. M. R., Biaou C., Egboou P. B., 2014. Caractérisation floristique et analyse des formes de pression sur les forets sacrees ou communautaires de la Basse Vallée de l'Ouémé au Sud-Est du Benin. Afrique SCIENCE 10(2) (2014) 243 - 257 243 ISSN 1813-548X,

[4] Cherifi K et Bouzidi M A., 2008. Approche préliminaire d'étude d'impact du surpâturage dans les Monts de Tessala (Wilaya de Sidi Bel Abbes), Université DjillaliLiabes, Sidi BelAbbes, Algérie, Colloque international « Développement durable des productions animales: enjeux, évaluation et perspectives », Alger, 20- 21 Avril 2008.

[5] Chalifoux S., Nastev M., Lamontagne C., Latifovic R., 2006. Cartographie de l'occupation et de l'utilisation du sol par imagerie satellitaire Landsat en hydrogéologie. Télédétection, vol. 6, n° 1, p. 9-17.

[6] Chikou, A., 2006. Etude démographique et de l'exploitation halieutique de six espèces de poissons-chats (Teleostei, Siluriformes) dans le delta de l'Ouémé au Bénin. Thèse de doctorat es Sciences biologiques, Université de Liège, Institut de Zoologie, Liège Pp 24-58.

[7] Congalton R. G., 1994. Accuracy assessment of remotely sensed data: Future needs and directions, Proceedings of the Percora 12 Symposium: Land Information from Space-Based Systems, Sioux falls, South Dakota, *American Society of Photogrametric and Remote Sensing*, pp 385-388.

[8] Denman, K. L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P. M., Dickinson, R. E., Hauglustaine, ., Heinze, C., Holland, E., Jacob, D., Lohmann, U., Ramachandran, S., da Silva Dias, P. L., Wofsy, S. C. et Zhang, X., 2007. Couplings Between Changes in the Climate System and Biogeochemistry. Climate Change 2007: The Physical Science Basis, Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, .B. Averyt, M.Tignor et H.L. Miller. Cambridge, Cambridge University Press, 499-588.

[9] FAO, 1999. Etude prospective du secteur forestier en Afrique (FOSA). Département des forêts. République du Bénin.

[10] Gareyane M, 2008. La sédentarisation des nomades dans la region de Gao. Révélateur et déterminant d'une crise multidimensionnelle au Nord Mali. Thèse de doctorat, Université Jean Moulin Lyon 3, Lyon, France, 287p.

[11] Hallouz F., Meddi M. &Mahe G. 2013.Etude des relations pluie/debit via les coefficients d'écoulement et le cumul de deficit de pluie dans le basin versant de l'Oued Mina (Nord Ouest d'Algérie).

[12] Haut-commissariat au Plan, 2006. Quelques éléments de l'intervention, Maroc, 6 pages.

[13] Houndagba C.J., Akoegninou F., Dannon G., Zannou G., 2007, *Etude de la dynamique des petits bassins lacustres du sud Bénin : cas des lacs Hlan et Sé-lé*, UAC, Rev.Univ., Lomé (Togo), n°003, pp 199-213.

[14] Igué A.M., Houndagba C.J., Gaiser T., Et Stahr K., 2006. Land Use/Cover Map and its Accuracy in the Oueme Basin of Benin West Africa).Conference on International Agricultural Research for Development.Tropentag, University of Bonn, www.tropentag.de.

[15] INSAE, 2013: Recensement Général de la Population et de l'Habitation. 2013. Quelques résultats Institut national de la statistique et de l'analyse économique, Cotonou, 39 pages

[16] Lalèyè P, Salako O, Chikou A, Philippart J-C. 2005. Artisanal gill-net fishery catches of the catfish, *Schilbentermedius*(Teleostei: Schilbeidae), in two tributaries of the Ouémé River, Bénin, West Africa. *African Journal of Aquatic Science*. 30 (2): 163-166.

[17] Lambin E.F., Geist H.J., Lepers E., 2003. Dynamics of land-use and land-cover change in tropical regions. *AnnualReview of EnvironmentalResources*, 28: 205-241.

[18] Le Barbé L., Alé G., Millet B., Texier H., Borely., Gualde D., 1993. *Les ressources en eaux superficielles de la république du Bénin*, ORSTOM/DH, Editions de l'ORSTOM, collection monographies hydrologiques n°11, 540 pages.

[19] Le Houerou, H.N., 1968. La desertification du Sahara septentrional et des steppes limitrophes. *Annales algériennes de géographie*, 6: 2-27.

[20] Leroux L., 2012. Analyse diachronique de la dynamique paysagère sur le bassin supérieur de l'Ouémé (Bénin) à partir de l'imagerie Landsat et MODIS– Cas d'étude du communal de Djougou, Rapport de stage, Hydrosciences Montpellier, ANR ESCAPE, 63 pages.

[21] Merle Caroline, Gautier Denis. 2003. Prélèvements de bois de feu dans les villages du sud de Maroua (Cameroun) : un modélisation. *M@ppemonde* (69) : pp. 13-19.

[22] Oloukoi J., Mama V. J., Agbo F. B., 2006. Modélisation de la dynamique de l'occupation des terres dans le département des Collines au Bénin. Télédétection, 6 (4) : 305-323.

[23] Ozer, A. &Ozer, P., 2005. Désertification au Sahel: crise climatique ou anthropique? *Bulletin des Séances de l'Académie royale des sciences d'Outre-Mer*, 51: 395-423.

[24] Pontius R.G. Jr., 2000. Quantification error versus location in comparison of categorical maps. *Photogrammetric Engineering and Remote Sensing*. Vol66(8).pp.1011-1016.

[25] Rachad M. A, et *al* 2015. Analyse des dynamiques sociales liées a une gestion apaisée de la transhumance dans la Basse et Moyenne vallée de l'Ouémé et sa zone d'influence en République du Benin, Rapport d'étude, Bénin, 79 pages

[26] Soumare S. (2008), Sanogo Z.J.L; Yossi H; Ouattara S; Kergna A.O. Perceptions des producteurs de la dynamique des systèmes de production agricole en zone guinéenne nord et soudanienne du Mali : Etude de cas dans les régions de Sikasso et de Mopti. Etude Sahel, Bamako, Mali, 105 p.

[27] Sogodogo A. 2015. Apport de la télédétection et des systèmes d'information géographique a l'étude de la dynamique des superficies agricoles dans la commune rurale de loulouni (sud du mali), mémoire de master, (CURAT) Université de Cocody, 63pages.

[28] Supit, I. 1997. Predicting national Wheat Yields using Crop Simulation and Trend Models. Agricultural and Forest Meteorology 88, 199- 214

[29] Tossa J., Fangnon B., , Babadjide C., Ogouwale E., 2016. Catastrophes hydroclimatiques : impacts agricoles et stratégies d'adaptation dans la Commune des Aguégués au Bénin, Rev. Ivoir. Sci. Technol., 27 (2016) 87 – 101, ISSN 1813-3290, http://www.revist.ci, 15p.

[30] Vodounou K.B. J., 2010. Les systèmes d'exploitation des ressources naturelles et leurs impacts sur les écosystèmes dans le bassin de la Sô au Bénin-Afrique de l'Ouest. Thèse de Doctorat, Université de Lomé, Togo, 308 p.

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