ORIGINAL ARTICLE

CLIMATE TRENDS AND DYNAMICS OF PERI-URBAN AGRICULTURAL AREAS: CASE OF ZINVIE IN THE MUNICIPALITY OF ABOMEY-CALAVI

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ABSTRACT

Background: The dynamics of occupation of peri-urban spaces constitutes a headache for producers who are already suffering the pangs of intra-seasonal variations. **Objective**: The objective of this research is to analyze the effects of climatic variability on the dynamics of formerly rural peri-urban spaces in the district of Zinvié in Benin. **Methods**: The methodology adopted is based on documentary research and field surveys. The analysis of climatological statistics (rainfall, temperature, humidity) over the period 1981-2017 made it possible to characterize climatic trends. Better still, data from the 2005 LANDSAT TM and 2015 OLI-TIRS satellites coupled with agricultural statistics, direct observations and direct interviews made it possible to assess the modes of occupation and the dynamics of the suburban spaces. **Results**: Research results show that human settlements have increased. Indeed, the analysis of land use maps shows an increase in human settlements which increased from 275.99 ha of the area of the district in 2005 to 417.18 km² in 2015, i.e. a rate of 66.15 % in 10 years. Added to this already bleak picture is the overall downward trend in rainfall totals (with two deficit sub-periods (1981-1986 and 1990-1994) on the one hand and the general upward trend in temperatures with values positive of the order of 0.06°C (for the minima) and of the order of 0.39 (for the maxima) on the other hand.
***Key words:** Zinvié district, climatic trend, suburban spaces and land use.*

1. INTRODUCTION

The analysis of the dynamics of the peri-urban space is relevant for the process of urbanization. This transition fringe, which mixes built-up areas and areas that are still rural, is a privileged observatory to define the modalities of the change in land use, - from rural to urban - and the role played by producers in this transformation. [1]. However, agricultural and urban uses, built and unbuilt spaces, adjoin and oppose each other within the dynamics of sprawl that have shaped diffuse, archipelagic urban spaces for the past thirty years [2].

Thus, taking agriculture into account in territorial projects linked to the city constitutes a legitimate social demand, linked to concerns around environmental issues (water quality), the living environment (health) and food security [3]. These environmental issues are undergoing large-scale modifications which remain amplified by natural and anthropogenic factors, both urban and rural, in a planetary climatic context in which the West African and Beninese climates are subject to strong variability or changes according to the scales of time and analysis, the consequences of which remain harmful for development [4]. The emerging question, correlative to climate change due to global warming, is that of the impact of a combination of high temperatures with low or even fluctuating rainfall levels and a greater concentration of atmospheric CO2 on the survival of certain cultivated species and crop yields [5]. For [6] precipitation remains the fundamental climatic element which conditions the various agricultural activities. Thus, their absence, rarity, excess or poor spatiotemporal distribution are generators of climate crisis. However, notes that it is not only the quantity of fallen water which conditions agricultural development, but also its good spatio-temporal distribution and the adoption of adequate cultivation techniques [7]. To promote the development of plant species. Furthermore, the strong population growth is a challenge for developing countries in general and particularly Benin which must house and feed its population whose number is constantly increasing because the need to meet the housing and agricultural needs of the growing population has led to changes in land use and occupation [8]. This has resulted not only in the loss of arable land that can be used for agricultural production, but also in the loss of the ecological functions of the soil (regulation of runoff water flows, reservoir and support for biodiversity, ability to capture CO2 through growth plants [9]. Like the other countries of West Africa, Benin and particularly its southern part, are experiencing a degradation of environmental resources, thus reducing their ability to meet the needs for survival and adequate development [10]. Indeed, the district of Zinvié in the commune of Abomey-Calavi in the South of Benin, is confronted with this situation characterized by a strong pressure of on the agricultural spaces. The population of Zinvié according to INSAE (2021) has more than doubled in 10 years with an annual intercensal growth rate of 6.7% between 2002 and 2013 against a growth rate of 9.43% between 1992 and 2002 [11].

The revolution in geospatial techniques in general, remote sensing and the geographic information system (GIS) in particular, allows an increasingly precise approach to knowledge and monitoring of the dynamics of land use [12]. The hypothesis posed in the context of this article is part of a climate trend context, which conditions the extension of cities and that agriculture is experiencing its crisis situation, contributing to the production of increasingly complex spaces. , intertwined, fragmented and heterogeneous, in a conflict of interest that works in favor of the urban [13].

In addition, the evidence of the vulnerability to climate trends of the weakened Beninese economy has been demonstrated by the work carried out as part of the development of the Initial National Communication and the National Strategy for the Implementation of the Convention. -United Nations Framework on Climate Change [14]. Faced with this situation, it is urgent to understand the current manifestations of climate recessions and their probable impacts on peri-urban agricultural spaces and that urgent measures be taken to reduce the vulnerability of populations to the adverse effects of climate change in Zinvié in the commune. of Abomey-Calavi. Figure 1 shows the geographic location of the study area.

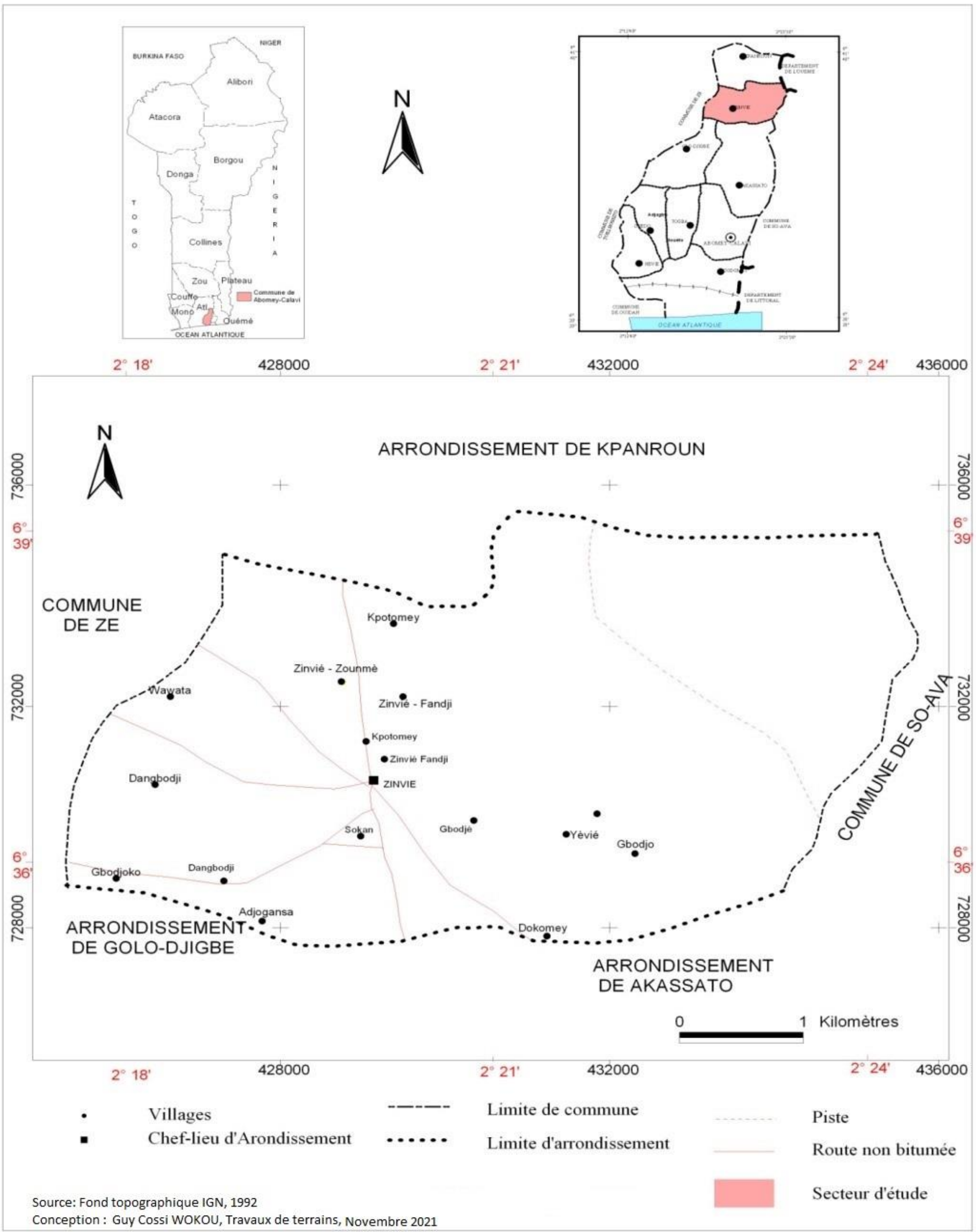

Figure 1: Geographical location of the district of Zinvié.

The Commune of Zinvié is located between 6°34' and 6°38' north latitude and between 12°19' and 2°24' east longitude, it is located in the south of the Republic of Benin in West Africa.

2. MATERIALS AND METHODS

The methodological approach adopted is based on the technique of quantitative and qualitative analysis. Data climatological (heights of rain and ETP of the Bohicon station) relating to the period1981 to 2017 were extracted from the ASECNA Cotonou data base. A wet year or a dry year is defined in relation to the Lamb index (the deviation from the mean normalized by the standard deviation) which is expressed by:

$$I\ (i) = (P(i) - P)\ /\sigma \qquad \textbf{(1)}$$

Where P(i) represents the average annual total obtained for year i;

P and σ respectively represent the average and the standard deviation of the series considered.

Thus, a year is considered normal if its index is between -0.1 and +0.1. It is said to be wet if its index is greater than 0.1 and dry below -0.1.

The significance of the difference in the means was verified by calculating the Student's T-test and the probability that the corresponding decades have significantly different means.τ

$$T = \frac{m_1 - m_2}{\sqrt{\frac{\sum_{i=0}^{N_1-1}(x_i - m_1)^2 + \sum_{i=0}^{N_2-1}(y_i - m_2)^2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}} \quad (2)$$

With x and y denoting respectively two consecutive decades. The hypothesis H0: x and y have significantly equal means is accepted if is greater than 5%.τ

The Khronostat 1.01 software was used to determine the dates of break in stationarity on the rainfall series studied. Franquin P.'s climate assessment is used. It reflects the rhythm of water surpluses or deficits. It expresses the difference between the total rainfall and the value of evapotranspiration (ETP), which constitutes the surplus available for soil water recharge and runoff. The climate balance formula is as follows:

$$Bc = P - ETP \quad (3)$$

With Bc = Climate balance in mm
P = total rainfall in mm;
If P – ETP < O, the balance sheet is in deficit;
If P – ETP > O, the balance sheet is in surplus;
If P – ETP = O, the balance sheet is balanced.

The water needs of watermelon are characterized by the phytosanitary state and stage of development of the plant. The variation of these water needs ETM the maximum evapotranspiration according to the development of the plant, will be determined by the crop coefficient Ke, an indicator which concerns only the crop and by the ETP.
The agricultural production statistics of the district and the socio-economic data obtained from the surveys carried out in the field have made it possible to identify the influence of the evolution of the surface conditions on the peri-urban agricultural spaces in the district of Zinvié.

LANDSAT TM satellite images from 1991, ETM+ from 2001 and OLI-TIRS from 2020 with a resolution of 30 m. these made it possible to produce land use maps for 1991 and 2020. To characterize the dynamics of the surface states in the study medium, a supervised classification was carried out following a colored composition using bands 2, 3.4 (TM and ETM+) and 3, 4.5 (OLI -TIRS) (green, red, near infrared). The validation of the classifications was carried out on the basis of surveys carried out in the field in the field and surveys of the populations. The statistics for each occupation unit, provided by Arc GIS, made it possible to characterize the dynamics of the units between 1991 and 2015. The calculation of the average annual rate of spatial expansion (T) is obtained from the transition matrix and based on the formula:

$$T = \frac{t_n - t_0}{t_0} \times 100 \quad (4)$$

T: being the rate of change of a land occupation unit between two dates;
t0: the surface area of a land occupation unit at the start year;
tn: the surface area of a land occupation unit ground in the year of arrival.

The sample size is determined by the formula of Schwartz (1995) [15]:

$$X = Z\alpha 2 \ xpq/i2 \quad (5)$$

In total, 100 people or 5% of the sample (05) five market gardening promoters were interviewed.
The individual interviews and the group discussion sessions were carried out using the questionnaires and the interview guide respectively to collect information from the resource persons. Direct observations in the field made it possible to better identify the strategies of market gardeners on the site.

3. RESULTS

3.1- Climate trends in the district of Zinvié

The climatic parameters studied concern precipitation, temperature, relative humidity and insolation in the study area.

3.1.1 precipitation: The figure 2 presents the rainfall regime of the district of Zinvié.

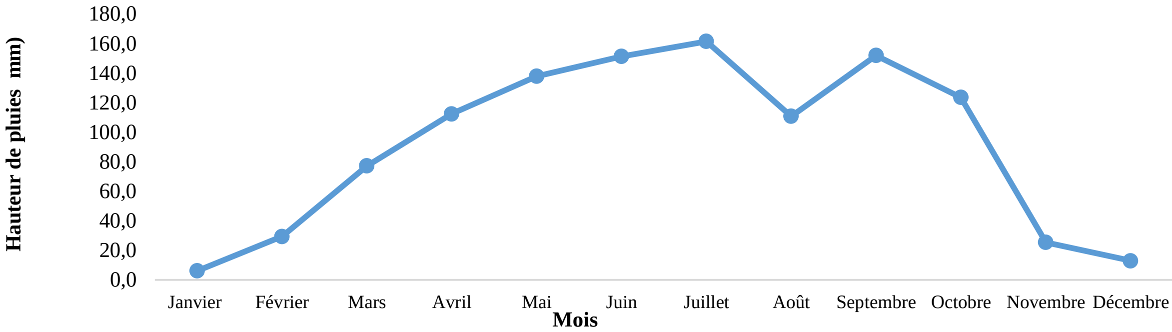

Figure 2: Rainfall regime of Zinvié over the 1981-2017 series. **Source**: ASECNA, 2020.

Analysis of Figure 2 shows that the climate of the Zinvié district is of the bimodal type: a large one from mid-March to mid-July and a small one from mid-September to mid-November and two dry seasons, a small from mid-July to mid-September and the big one from mid-November to mid-March. There is a disturbance in the rainfall recorded during the two rainy seasons which condition the development of crops. Deficit and surplus indices were noted during the 1981-2017 study baselines to better analyze rainfall trends (Figure 3).

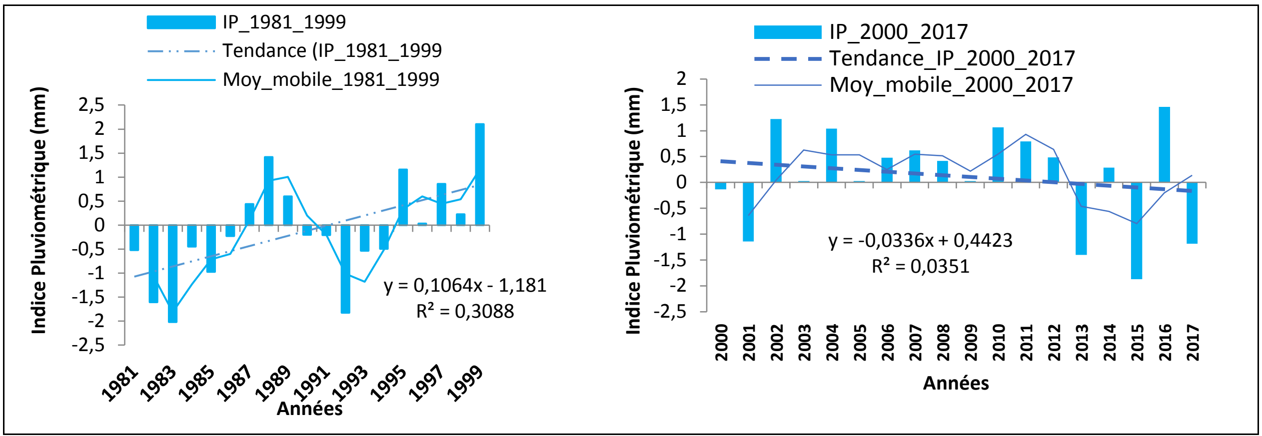

Figure 3: ISP indices over the periods 1981 to 1999 and 2000 to 2017inthe district of Zinvié. Source : ASCENA data, 2021.

The analysis of Figure 3 generally shows an upward trend from 1981 to 1999. This reflects a period which as a whole is marked by the abundance of the quantities of rainfall. The period 1981 to 1999 recorded two deficit sub-periods (1981-1986 and 1990-1994) and two other surplus sub-periods (1987-1989 and 1995-1999) with deficit years (11) more numerous than surplus ones (07). The general upward trend is explained by the largest surplus peak (2.10) which is almost double the other surpluses during 1999 alone. In reality, the rainfall deficit is remarkable, being explained by several pockets drought and floods at times attesting to the presence of these climatic hazards in the study area.

From 2000 to 2017, the trend is rather generally downward, reflecting a rainfall deficit overall, while in this series the surplus years (2002 to 2012, 2014 and 2016) are more numerous (13) than those (2000, 2001, 2013, 2015 and 2017) loss-making (5). The general deficit observed is rather relative to the largest peak (-1.87) of deficit observed in 2015 over the entire sub-period. This period is actually characterized by recurrent floods in 2008, 2010 and 2014, while the other entire years highlight the delays in rainfall, their irregularity which requires an analysis on the years are wet and dry in the study area.

Table 1: Characteristics of wet years in the district of Zinvié.

SPI values	Periods		Features
	1981-1999	2000-2017	
SPI>2	12.5%	00%	Extreme humidity
1<SPI<2	25%	30.77%	high humidity
0<SPI<1	62.5%	69.23%	Moderate humidity

***Source:** Data processing, 2017*

Examination of the table shows that over the period 1981-1999, 12.5%, 25% and 62.5% of the years have respectively extreme, high and moderate humidity compared to 00%, 30% and 69% of the years over the period2000-2017. It appears that overall the study area is characterized by moderate humidity. The paradox is that despite the floods of the years 2008, 2010 and 2014, the second period recorded 0% extreme humidity and 30% high humidity. Analysis of the characteristics of dry years shows a different pattern.

Table 2: Characteristics of dry years.

SPI values	Periods		Features
	1981-1999	2000-2017	
-1<SPI< 0	16.67%	20%	moderate drought
-2<SPI<-1	16.67%	80%	Severe drought
SPI<-2	66.67%	00%	Extreme drought

Source: *Data processing, 2021.*

Examination of the table shows that there are16.67%; 16.67% and 66.67% years over the period 1981-1999 then 20%; 80% and 00% of the years over the period 2000-2017 experienced respectively moderate, strong and extreme dry spells. It thus appears that there has been no extreme drought for almost two decades even if the severe drought is observed at 80%.

If the analyzes made above showed a moderate evolution of the characteristics of humidity, those of the droughts, on the contrary, showed an increase. This continued moderate decline in wet years and the gradual change in dry years are due to the "Sahelization" of the climate. This is manifested by the appearance of longer and longer dry spells, and the shortening of the rainy seasons. These have as negative impacts, the suffering of crops in water needs and the delay in the growth of plants with the immediate consequence of lower yields.

- ✓ **Characteristics of dry sequences in the study area**

Dry sequences during the growing season benefit from sustained attention from producers. The longer they are, the more they affect the phenological development of crops. The different forms of dry sequences in the Alibori department are shown in the figure.

3.1.2 Temperature trend

Temperature is a determining factor in agricultural production.

✓ **Monthly temperature variation**

Figure 4 presents the average temperature regime of the study area from 1981 to 2017.

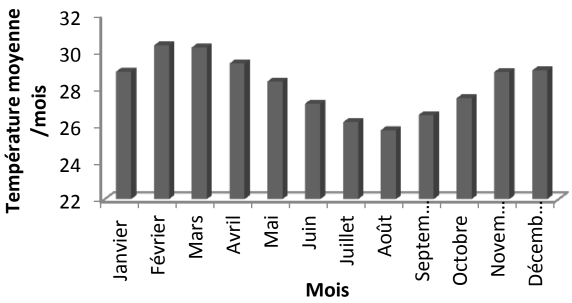

Figure 4: Average temperature from 1981 to 2017.
Source: *Data processing, June 2021.*

Analysis of Figure 4 shows that the highest temperature is recorded in March (30.23°C). This high temperature in March from 1981 to 2017 reflects the concentration of heat recorded during the months of great drought, which emerges especially in mid-March when the first rains start. From these first rains, temperatures dropped from 30.23°C to 25.74°C from March to August where the lowest (25.74°C) temperature over the entire series is recorded.

✓ **Segmentation of the interannual temperatures of1981 to 2017**

Temperatures experienced a break in stationarity (Figure 5).

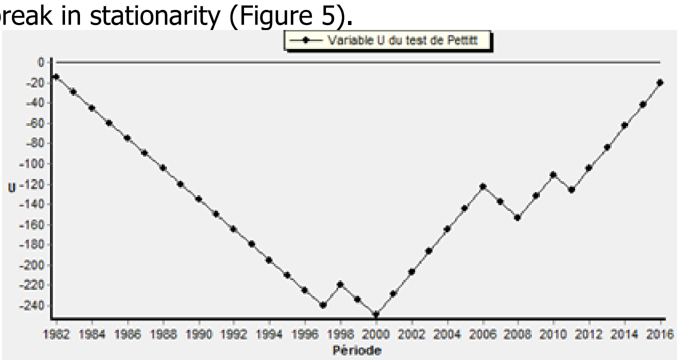

Figure 5: Evolution of the variable U of the Pettitt tests applied to the series of minimum temperatures from 1981 to 2017. ***Source***: *Data processing, November 2021.*

It emerges from the figure that a break in stationarity was observed during the year 2000. There appear two major sub-periods, in particular the wet period from 1981 to 2000 and the dry period from 2000 to 2017.

- ✓ ***Thermometric index***

Figure 6 presents the interannual temperature indices.

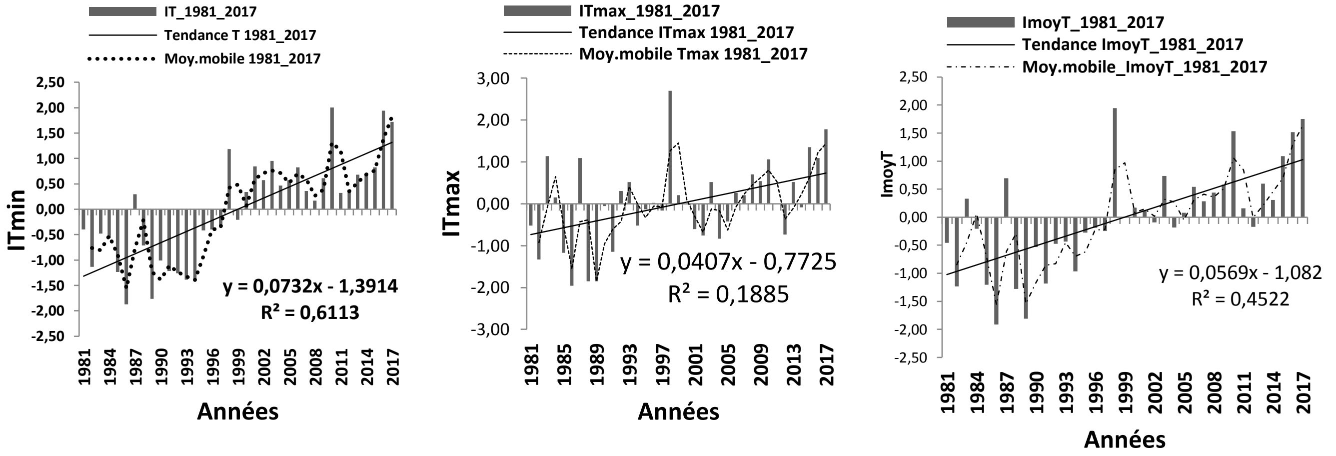

Figure 6: Maximum, minimum and average Zinvié thermometric index from 1981-2017. ***Source of data:****ASECNA, 2018 and data processing, July 2021.*

Analysis of the regression lines of the graphs in the figure shows an upward trend in maximum, minimum and average temperatures over the period 1981-2017. This trend increase is supported by the positive values presented by equation (y). The last two decades have been characterized by warming with high temperatures. This is explained by the values of the thermometric anomaly which remained constantly positive. This context increases evapotranspiration and causes plant dehydration.

- ✓ **Interannual temperature variation**

Comparing the means of the 1981-1999 and 2000-2017 subseries shows that the second subseries has higher temperatures than the first (figure).

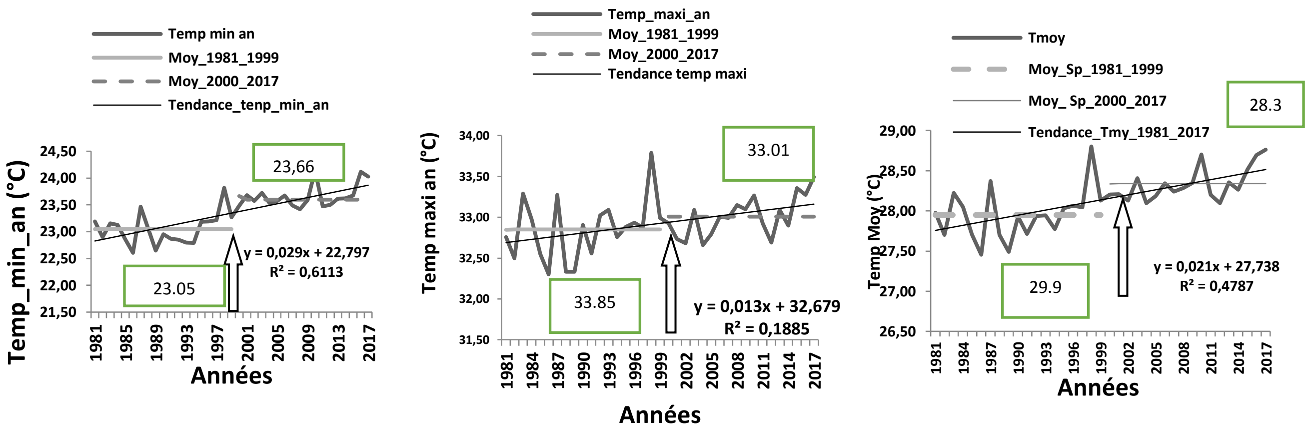

Figure 7: Interannual evolution of maximum, minimum and average temperatures from 1981 to 2017. ***Source of data:*** *ASECNA, 2018.*

From the analysis of the figure, it is noted a general trend of increasing temperatures with positive values presented by (y) ranging from 1981 to 2017. In addition, it is noted a slight increase in the minimum temperature of the order of 0.06° C and average of about 0.39 with a regression at the level of the maximum temperature (-0.16) during the second sub-series. Thus, between 1981-1999 and 2000-2017, the maximum, minimum and average temperatures increased respectively from 23.05°C to 23.66°C, from 33.85°C to 33.01°C and from 27.9 °C to 28.3°C. This finding is illustrated by the relatively high value of the coefficient of determination of equation (R2). The increase in temperatures in the department of the study area sometimes exceeds the thermal needs of certain crops, leading to losses in harvesting posts and, by extension, losses in terms of financial investment, especially with peasant strategies (wear) of very restrictive financing. Thus the climate is a factor that aggravates the financial vulnerability of grassroots producers.

3.2. Characteristics of the peri-urban space in Zinvié

3.2.1 Land tenure in the study area: Land tenure in Zinvié is characterized by the worsening of land destabilization in recent years. It manifests itself in the individual appropriation of land through the system of sale. The latter has developed rapidly due to the monetarization of the economy. Thus, traders, civil servants and other categories coming from Cotonou, Godomey, Calavi, and other localities accentuate the purchase of land in Zinvié (field survey, 2020). Added to these elements is the demographic pressure which has favored the fragmentation of many family or collective estates.

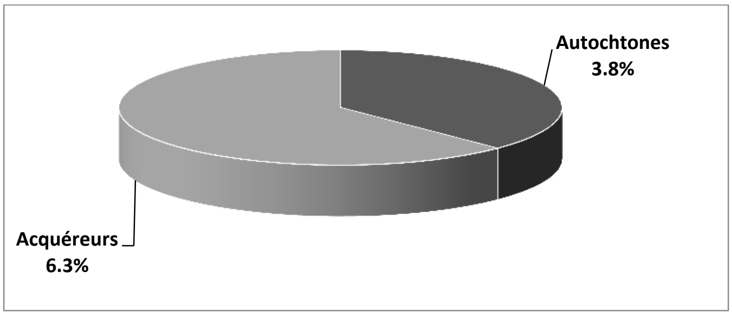

Figure 8: Land tenure in Zinvié. ***Source***: *Field survey, 2021*

From the analysis of Figure 8, it appears that the proportion of landowners in the district of Zinvié is lower than that of buyers. This shows that the natives of the area have sold a good proportion of their state possessions. In addition, the surveys carried out show that 37.5% of the occupants own land in Zinvié and 62.5% are buyers (Figure 7). They benefit from all rights of use on the landed properties under their responsibility. In the past, landowners could grant their land to other people in various forms: gift, loan or pledge. Today, with the land pressure, the land is sold more and more, hence the market and speculative value which explains the constantly increasing evolution of the prices of the plots in Zinvié.

3.2.2 Mode of access to land

In the Arrondissement of Zinvié, land is acquired by inheritance, purchase, pledge or loan. Figure 9 shows the proportion of the different modes of access to land in use in the district.

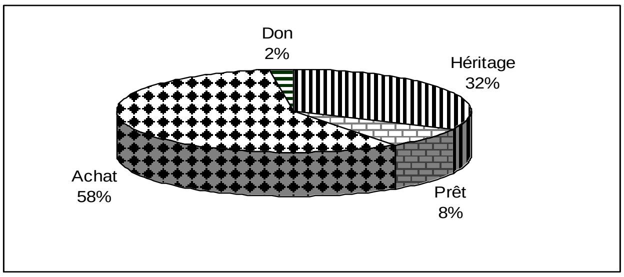

Figure 9: Mode of land acquisition in Zinvié. ***Source***: *Field survey, 2021.*

The analysis of Figure 9 shows the mode of land acquisition in Zinvié. This figure shows that access by inheritance, purchase, gift and loan are the modes of access to land in the district of Zinvié.The mode of access to land by inheritance comes in second position (32%) after purchase (58%); which was not the case according to the populations surveyed. Access to land by purchase is currently the most fashionable method in the Zinvié district (58%). In effect, the existence of so-called owners (especially indigenous heirs) who sell the same plot to several buyers has been reported. This situation is often the cause of land disputes in the study area. In Zinvié, only 7% of the women surveyed inherited plots from their parents. Currently, it is mainly intellectual women who fight for women to enjoy land inheritance rights everywhere and always. Modes of access to land by donation and loanpractices are gradually disappearing because of the non-respect of commitments, the desire for expropriation of land by the beneficiaries and above all the monetary value that the land assumes.

3.3. Dynamics of peri-urban agricultural spaces and land use between 2005 and 2020

3.3.1. Dynamics of land occupation units

Figure 10 shows the evolution of space in the borough concerned by this study.

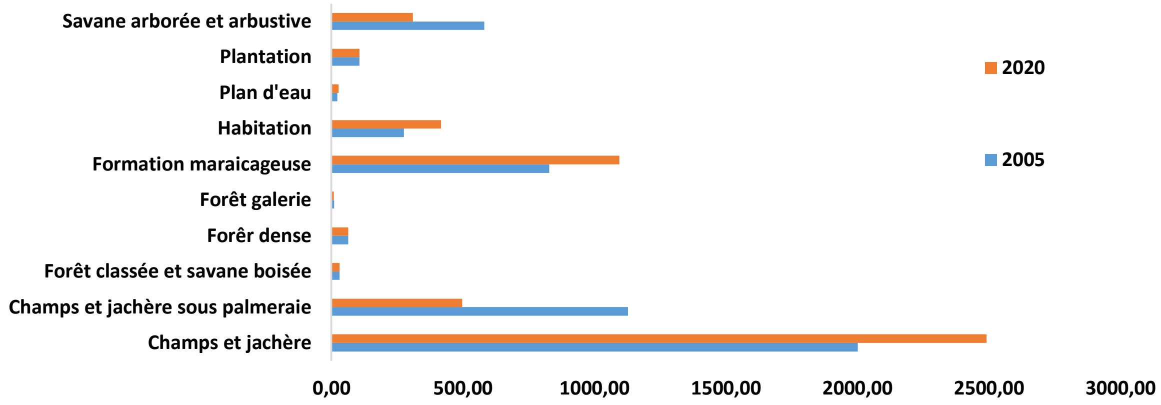

Figure 10: Land Cover Units.

Analysis of Figure 10 shows that the area of each land use unit that has not changed from 2005 to 2020 is that of classified forest and wooded savannah (31.29), plantation (107.232 ha) and dense forest (63.75 ha). The area of each land use unit having undergone change but not significant are those of gallery forest regressively from 10.62 ha to 9.43 ha, bodies of water gradually from 22.62 ha at 27.98 ha. Finally, the area of occupation units that have undergone significant change are those of fields and fallow land gradually from 2001.95 ha to 2491.50 ha, marshy formations progressively from 828.01 to 1094.88 ha, tree and shrub savannas in a regressive manner from 581.859 to 309.96 ha over a period from 2005 to 2020. The regressive evolution of wooded and shrubby savannahs is explained by the phenomenon of urbanization in the study area according to 95% of respondents. In order to improve their yield, which has become low due to the vagaries of the weather, producers are obliged to plow more cultivable land. Figures 11 and 12 are the land use dynamic maps for 2005 and 2015.

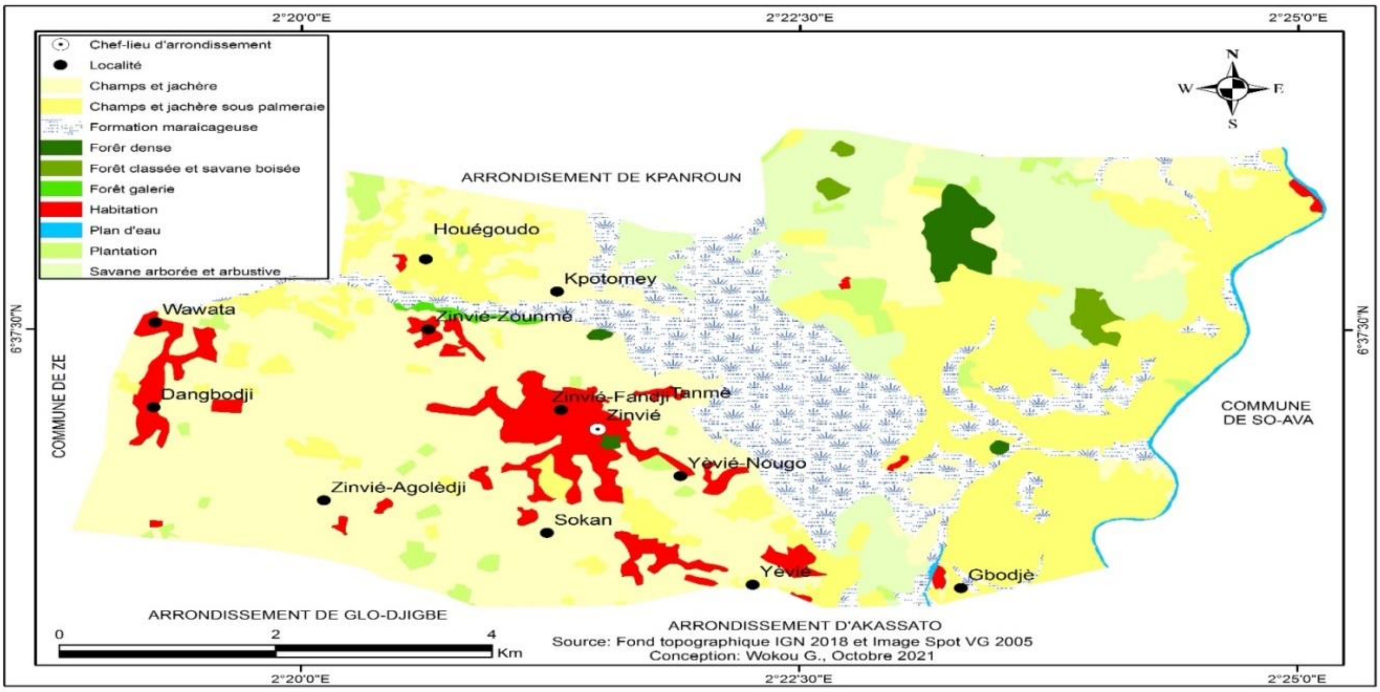

Figure 11: Land use in the borough in 2005.

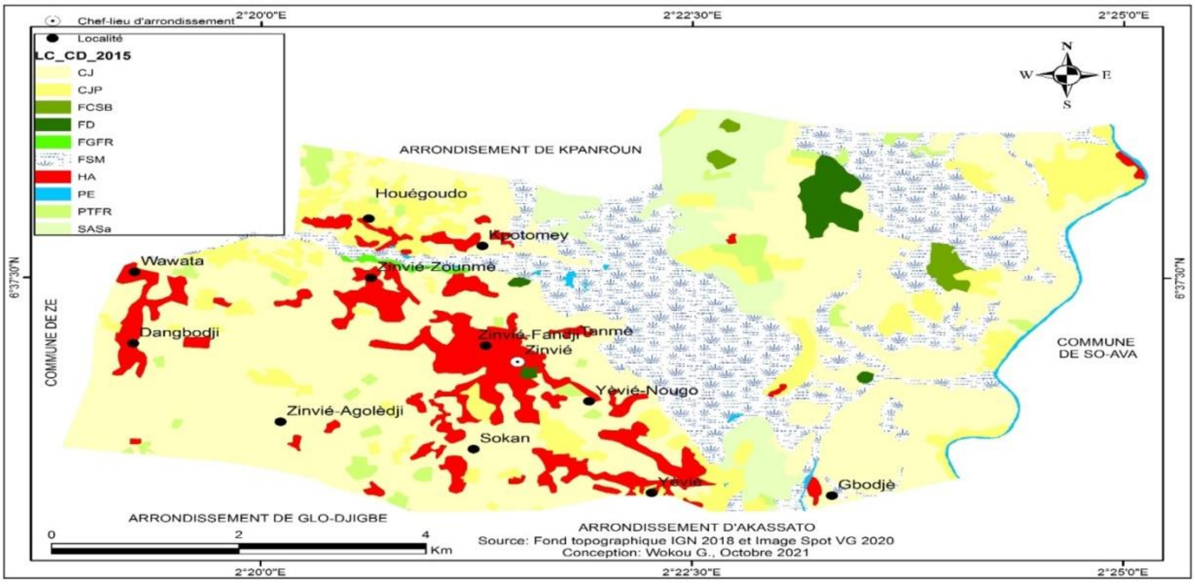

Figure 12: Land use in the borough in 2015.

4. DISCUSSION

Their approach follows the observation that existing urban planning documents hardly take into account the specificities of peri-urban agriculture as an economic activity requiring developments that are not necessarily adapted to the urban vision of agricultural spaces. Moreover, Doukpolo (2014, p.14) [16], corroborates and emphasizes, among other things, sustainable land management as one of the adaptive measures in the face of the pessimistic climate scenario and a sharp decline in yields.

The findings of others authors [11, 3] corroborate and emphasize, among others, sustainable land management as one of the adaptive measures in the face of the pessimistic climate scenario and a sharp decline in yields. The findings of Dovonou et al, (2017, p111) [11], Sanz et al, (2017, p.187) [3] as well as Valette (2014, p.114) [2] agree on the issue of the dynamics of peri-urban agricultural spaces. Dovonou et al, (2017, p111) [11], showed that from 1991 to 2015, land use has evolved in a trend of pronounced degradation of agricultural spaces and a progression of facilities of anthropogenic origins. Buildings have taken over and continue to progress, swallowing up green spaces, leading to a gradual and definitive disappearance of the city's green belt. As for Sanz et al (2017, p.187) [3], it appears that contrary to conventional wisdom, distance from the reference city-center is not a determining criterion for characterizing agriculture in the outer and inner limits of the peri-urban. The different forms of peri-urban agriculture are not distributed along a gradient of distance to the city according to their technical-economic vocations, as a simplistic application of an approach. Finally, Valette (2014, p.114) [2] specifies that the agricultural question is likely to invest the field of urban planning in multiple forms because the growing quest for space for housing, the need to ensure the supply of cities through a reorganization of food systems, promote, in industrialized and emerging countries, the emergence of solutions that are very economical in terms of space and manpower [17]. Based on this scheme, agri-urbanism can cover totally different experiences, initiated by municipalities, which aim to relocate agriculture and its outlets in and around cities, via the organization of shared land use; or by civil society, which contributes daily to the invention of new forms of urban agriculture.

5. CONCLUSION

At the end of this study, it was possible to highlight the trend of the dynamics of peri-urban agricultural spaces between 2005 and 2020, to determine the effect of climate trends on these areas. Thus, based on LANDSAT TM, ETM+ and OLI-TIR images from 1991 and 2020, this study has shown the worrying increase in human settlements and the sharp decline in agricultural areas. From 2005 to 2020, the occupation of the land evolves in a tendency of pronounced degradation of the agricultural spaces and an increase in the installations of anthropic origins. Buildings have taken over and continue to progress by swallowing up green spaces. We are witnessing a gradual and definitive disappearance of the green belt of the municipality. The first cause of such a situation is the strong demographic growth combined with the climatic deteriorations which oblige to more important sowings.

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