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# Climate change and farmland dynamics in the Collines Department of Benin (West Africa)

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## Abstract

This study, the general objective of which is to study climate change and analyze the dynamics of crops in the Collines department.

This research is carried out using a general methodology (documentary research and field work with a sample of 80 farmers surveyed. Statistical analysis of temperature from (1975 to 2015), rainfall from (1975 to 2015).

The results of this research show that farmers have noted climatic disturbances in recent years. This manifests itself in a reduction in the number of days of precipitation according to 95% of respondents, a drop in agricultural yields according to 100% of farmers surveyed, shortening the duration of rainy seasons according to 100% of respondents, strong insolation according to 90% of respondents. surveyed, an increase in the duration of dry seasons according to 72% of respondents and destruction of crops according to 75% of respondents. Thus, farmers attribute deforestation and non-respect of social norms and traditions as the cause of climate change. Faced with this situation, farmers have developed various strategies such as modifying technical planting dates and adopting new varieties.

**Keywords:** Collines Department; Climate change; Land cover

## 1. Introduction

Climate change and its impacts are currently one of the most pressing issues for the international scientific community. The African continent is subject to a highly variable and unpredictable climate, which weakens agricultural systems that are no longer able to cope with current climate pressures (1). This continent is particularly vulnerable to climate change due to the strong dependence of its economies on agriculture and the limited adaptive capacities of its populations (Kurukulasuriya et al. 2006, p. 367).

Benin, a developing country in West Africa, is not immune to the threats posed by climate change. Agriculture, the foundation of the Beninese economy, contributing 40% to the gross domestic product (GDP) and more than 80% of export earnings (Doligez, 2001, p. 40), is already suffering from the negative impacts of climate change (PANA-Benin, 2008; Yegbemey et al., 2014, p. 177). The agro-climatic conditions present particular challenges for agriculture, especially in the hills, which sometimes experience severe droughts (MEPN, 2008, p. 81). From the work of M. Boko (1998, p. 50), A. Afouda (2007, p. 23), and E. Ogouwalé (2004, p. 119), it is clear that worsening rainfall patterns, a shorter agricultural season, persistent negative weather anomalies, and rising minimum temperatures now characterize Benin's climate and alter rainfall patterns and agricultural production systems. Indirectly, climate change

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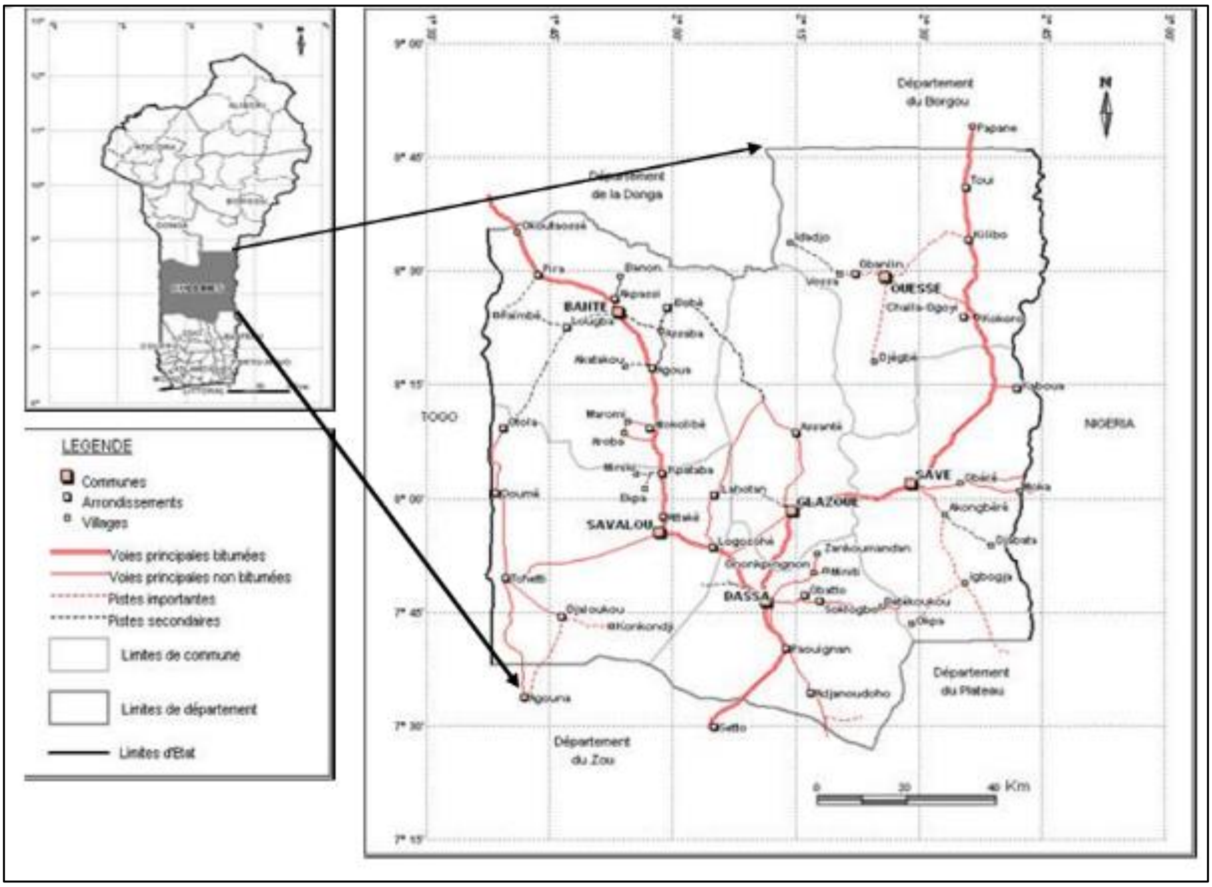
also impacts the agricultural workforce, agricultural commodity prices, and agro-industrial processing units (MEPN, 2007, p. 102).

According to E. Ogouwalé (2006, p. 302), additional heat stress and drier soils risk reducing yields in various agro-ecological regions. Disasters caused by climate change phenomena have a significant impact on agriculture in developing countries (F. Sperling et al., 2003, p. 51). From the work of M. Boko (1988, p. 50), A. Afouda (1990, p. 23), Dansou (1999, p. 13), and E. Ogouwalé (2004, p. 119), it is important to understand that food crises are a consequence of the dynamics of climate change over the last three decades. That is to say, variations in rainfall and temperature affect local crops.

Furthermore, the effects of climate change are perceived differently by farmers, who develop different strategies (Selvaraju et al. 2006, p. 83). The adaptation practices developed by producers in response to the negative consequences of climate change depend on their perception and their local knowledge of these changes (R. Dimon, 2008, p. 132). Community support for local climate change adaptation actions is effective if these actions incorporate their local knowledge (Kanté, 2011). It is therefore important to study climate change and analyze crop dynamics in the Collines department.




Source: IGN background, 1992

**Figure 1** Geographical location of the Collines department

## 2. Methodology

### 2.1. Data used

- The climatological data (rainfall and temperature, etc.) and potential evapotranspiration (decadal and monthly) used in this study cover the period from 1975 to 2015. They were collected at the National Meteorological Directorate (DMN) at Météo-Benin.
- Agricultural statistics relating to planted areas per hectare, production in tonnes and pineapple production yields, taken from the MAEP agricultural statistics compendiums for the period from 2000 to 2010.

- Spatial data related to land use: Ouèssè map sheet at a scale of 1/50000, techniques for acquiring, processing, analyzing and interpreting images obtained by specialized satellites.
- Qualitative information from socio-anthropological investigations has made it possible to understand climate change and to identify the adaptive measures that people are developing to cope with it.

### 2.2. Materials, tools and data collection techniques

*2.2.1. Collection materials*

The equipment used consisted of a digital camera, a GPS (Global Positioning System), and a laptop computer which facilitated internet research. This equipment was used respectively to take snapshots of the different types of plants and to georeference them precisely.

*2.2.2. Measuring instruments and equipment*

The materials used are listed in Table I.

**Table 1** Materials and their uses

| Elements | Materials | Usefulness of the equipment |
|---|---|---|
| Basic cards | Location map<br>Land use maps<br>SPOT image extract | Situation of the terroirs<br>General knowledge of local areas<br>Diachronic study |
| Work software | Word and Excel | Text entry and statistical processing |
| Mapping instruments | Rotring – Trace - letter<br>Trace - circle | Map creation |

Source :Field survey results, April 2024

*2.2.3. Data collection tools*

Several tools were used in the collection of data in the field.

- The questionnaires are sent to farming households in order to assess, above all, their knowledge and practices regarding production techniques;
- The guide for group interviews (focus group) in order to collect qualitative data complementary to observations and individual interviews, and also to have the best communication channels in each village or district.
- The guide to observing the condition of fields during the different phases of agricultural production.

*2.2.4. Data collection technique*

The literature review was conducted at research centers, services, and institutions whose activities are related to the subject of this study. Specifically:

- The Laboratory for the Study of Climates, Water Resources and Ecosystem Dynamics (LECEEDE) and the Faculty of Arts and Humanities (FASHS) and the university's central library;
- The National Institute of Statistics and Demography (INStaD);
- The Ministry of Agriculture, Livestock and Fisheries (MAEP) and the Territorial Agency for Agricultural Development (ATDA).

### 2.3. Field investigations

The study was conducted in the Collines Department. The population studied consisted of agricultural producers and households. The villages surveyed were composed of the Idaatcha, Fon, and Mahi ethnic groups.

*2.3.1. Sampling*

The sample was focused on the municipalities within the Collines department. The choice of these districts was based on reasoned considerations, taking into account the selection criteria, the extent of degradation, the importance given to agricultural production, and the presence or absence of conflicts.

The sample size is 80 households. These primarily consist of agricultural migrants, with a focus on farm managers. Other research units considered include groups of indigenous farmers, customary authorities, representatives of the sub-prefectural producers' union, rural development workers, and forestry officials.

## 2.4. Method for processing data and analyzing results

### *2.4.1. Data processing method*

The data collection forms were analyzed in the database using IBM SPSS Statistics 21 software (statistical processing with Excel 2016 integration).using the Xlstat 2008 softwarein order to create tables, figures, and graphs. This involves: cLassification on hierarchical factors, tree cut and class description, characterization of typology classes.

## 2.5. Method for analyzing results

### *2.5.1. Method for analyzing stationarity breaks*

The Pettitt break detection test (Snijders, 1983; Demarée, 1990; Vanitsem and Démarée, 1991; Coops, 1992), whose null hypothesis is the instability of the equality of means of two subseries derived from the initial series (Lawson-Body, 2002), al lows us to identify major periods of change in rainfall, the number of rainy days, temperatures, and heavy rainfall. A break can be defined as the point at which a sudden change or jump occurs in a time series (Pettitt, 1979). Each subsample obtained is also subjected to this test, thus subdividing the series into generally homogeneous periods with means that are significantly different from one another.

### *2.5.2. Pettitt Test*

The non-parametric Pettitt test is derived from the Mann-Whitney U test. The absence of a break in the N-sized series Xi constitutes the null hypothesis. The implementation of the test assumes that for any time t between 1 and N, the time series (Xi) i=1 at t and t+1 at N belong to the same population (B. Doukpolo, 2014, p. 51).

This test is based on the calculation of the variable Ut, N defined by: U t, N = where Dij = sgn (xi – xj). With sgn (Z) = 1 if (Z) > 0; 0 if Z = 0 and -1 if Z < 0.

Let KN be the variable defined by the maximum absolute value of Ut, N for t ranging from 1 to N-1. If K denotes the value of KN taken from the studied series, under the null hypothesis, the probability of exceeding the value K is given approximately by: Prob (KN > K) ≈ 2exp (-6K2 / N3 + N2). For a risk□□of a given first kind, if Prob (KN > K) is less than□□The null hypothesis is not rejected.

### *2.5.3. Buishand Test and Wood Ellipse*

The Buishand test is a parametric test whose statistic is defined as the maximum of the cumulative sum of deviations from the mean or median (detecting a break in a time series). Since the alternative hypothesis of this test is a sudden change in the mean, the power function is estimated by generating series from independent normal variables with the same variance but exhibiting a break in the mean, starting from a randomly chosen individual (Lubès-Niel et al., 1998, cited by B. Doukpolo, 2014, p. 51).

The statistic used in this test is: $t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(S^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)\right)}}$

With $\bar{X}1$ = Average before the year of break; n1 = Number of elements in the first series; n2 = Number of elements in the 2nd series.

$S^2$ denotes the weighted variance of the entire group of the two samples, i.e.:

$$S^2 = \frac{\sum_{i=1}^{n_1}(X_{1.i}-\bar{X}_1)^2+\sum_{i=1}^{n_2}(X_{2.i}-\bar{X}_2)^2}{n_1+n_2-2}$$

The Pettitt test involves dividing the main series of N elements into two subseries. At each time step, t is between 1 and N-1. The main series shows a break at time t if the two subseries have different distributions. The Pettitt test was chosen for its use in numerous studies detecting changes in stationarity in West Africa (Koumassi, 2014), for its power, especially with regard to the break test (Lanokou, 2016), and for its robustness (Codjo, 2017).

# 3. Results

## 3.1. Analysis of climate trends

Climate variability can be considered as statistically significant variation in the average state of the climate or its variability, persisting over a prolonged period (generally decades) (E. Ogouwalé, 2006, p. 302). The climate factors considered in determining these climate change indicators are precipitation (amount and number of rainy days) and maximum and minimum temperatures.

### *3.1.1. Analysis of rainfall trends*

The basin's climate is regulated by the West African Monsoon (WAM) system, defined as a vast seasonal low-altitude circulation pattern resulting from thermodynamic contrasts between the continent (particularly the hot, dry Sahara) and the tropical Atlantic Ocean (O. Koudolamiro, 2017, p. 89). D. Kodja (2013, p. 45; 2017, p. 20) emphasized that the monsoon relies on the seasonal migration of the Intertropical Convergence Zone (ITCZ), defined as the meeting of continental and oceanic atmospheric circulations towards its northernmost location in August. This convergence zone, combined with solar radiation, induces unstable thermodynamic conditions over the West African continent, causing heavy convective rainfall.

The value of studying rainfall parameters lies in comparing theoretical results with the perceptions of local populations.

In order to better examine the trend in the evolution of the theoretical data from 1975 to 2015, Figure 2 shows the evolution of rainfall amounts during the year that were carried out.

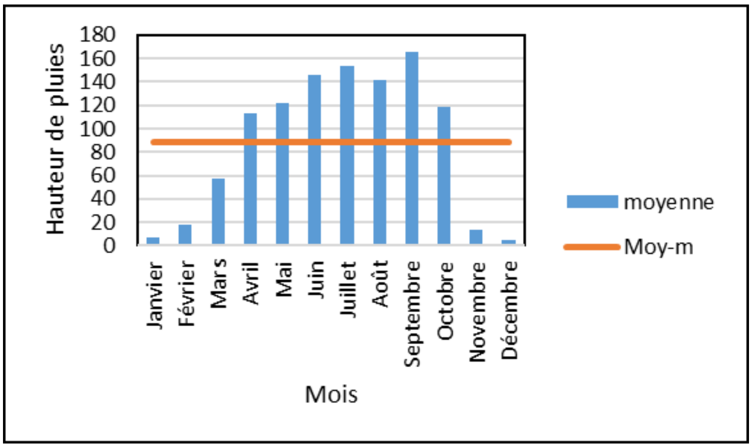



**Figure 2** Evolution of average monthly rainfall (1985-2015)

Analysis of Figure 2 shows that in this area, the rains begin and intensify as early as March, ending around November or December. After the onset of the rains in April, the rainfall becomes more abundant, peaking between July and September with a maximum rainfall of 155 to 170 mm. The rains cease in the area in October.

The calculation of rainfall indices makes it possible to distinguish between dry, normal and wet years (Figure 3). These indices show the standardized deviations of annual rainfall in the study area over the period from 1917 to 2015.

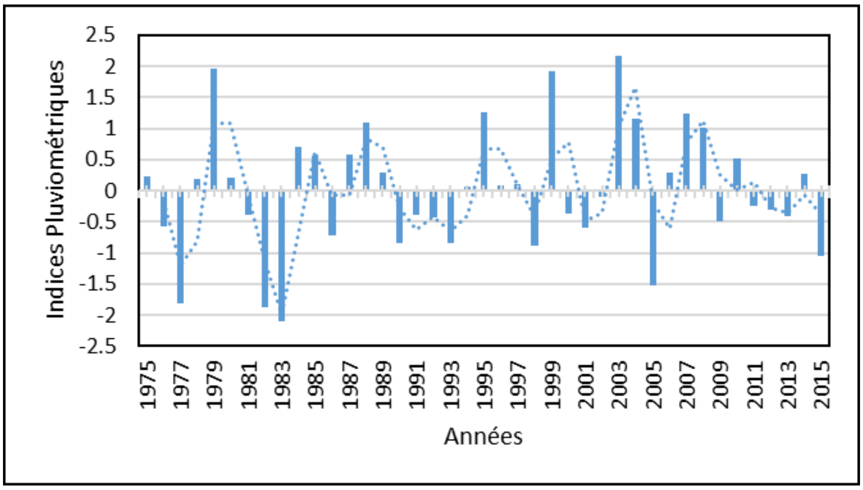



**Figure 3** Standardized Rainfall Index

An examination of the interannual variability of rainfall indices during the period 1975-2015 reveals an alternation between wet years and dry years.

*3.1.2. Thermometric trend analysis*

Temperature is one of the fundamental components of the hydrological cycle and climate. It is linked to solar radiation. Its variation influences the transformation of water into vapor, whether at the surface or underground (E. Amoussou, 2010).

Temperature is one of the climatic factors that determine crop yields. This section analyzes the minimum and maximum temperatures in the district over a 40-year period.

The evolution of minimum temperatures in the Collines department over the period from 1975 to 2015 (figure 4).

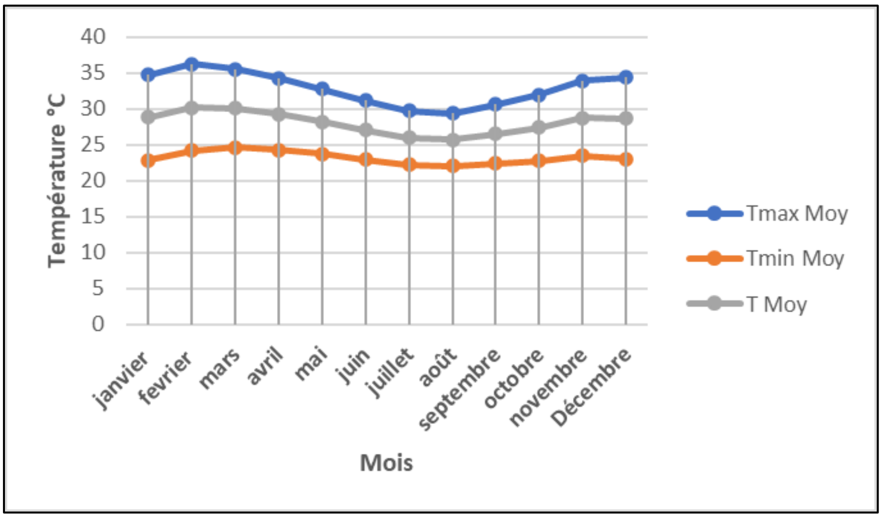



**Figure 4** Monthly temperature evolution in the Bohicon hills department from 1975 to 2015

Analysis of Figure 4 shows that temperatures vary throughout the year, ranging from 21 to 36°C, with an annual average of 28.02°C. The highest maximum temperatures are recorded in February (36.18°C) and the lowest in August (21.98°C). The period from November to April is characterized by severe drought, while December and January are marked by the harmattan, a cold, dry wind.

*3.1.3. Analysis of stationarity breakdown in rainfall records*

In Africa, several previous works (M. Badolo, 1993, p. 137; S. Ardoin-Bardin, 2004, p. 76; H. Ganga et al, 2016, p. 214) based their analyses on certain parametric tests, including Pettitt's test and Hubert's segmentation procedure to characterize changes in rainfall records.

In Benin, (H. Koumassi, 2014, p.71), O. Koudolamiro (2017, p.57), E. Atiye (2017, p.69) determined points of change and divided the original series into sub-series in their study of stationarity of hydrometeorological series.

The stationarity break was performed using rainfall data from the Cotonou synoptic station. Figures 5 and 6 show the Pettitt and Buishand tests applied to the annual rainfall series (1961-2015).

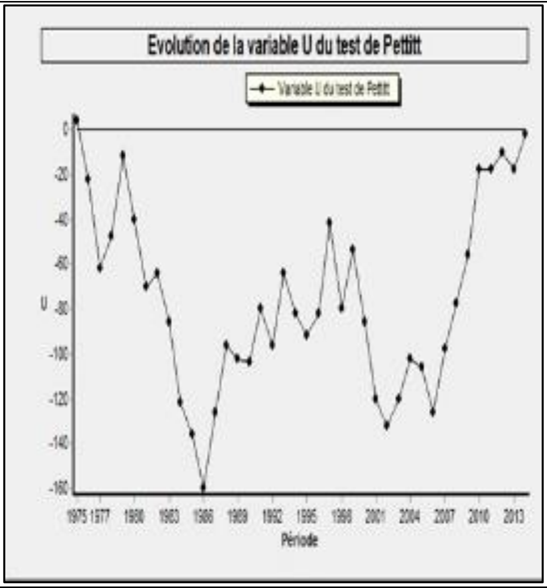



**Figure 5** Evolution of the variable U in the Pettitt test

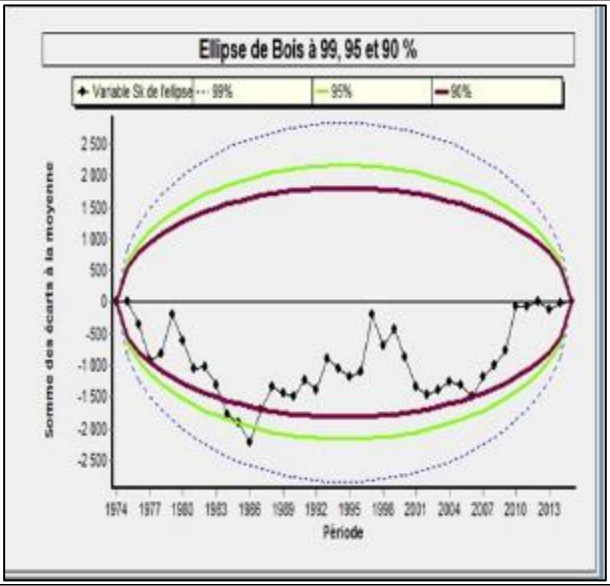



**Figure 6** Variable Sk of the wooden ellipse (Buishand test)

Petit's test, supplemented by Buishand's test applied to the rainfall series in this study, shows a break in stationarity at a 99% confidence level. Annual rainfall amounts exhibit interannual variability, with a break occurring in 1986 in the study area.

Starting from 2007, the year of the rainfall disruption, two sub-periods emerge, notablyof rainfall recession from 1975 to 1986 and the period of recovery in rainfall levels from 1987 to 2015.

### 3.2. Manifestation of climate change

The main manifestations of current climate change include late and heavy rainfall, flooding, pockets of drought, excessive heat, torrential downpours, and strong winds. Livelihoods most vulnerable to these risks include family-run farms. These include cash crop production systems, food and vegetable crops, livestock farming, and inland and marine fisheries. Smallholder farmers remain the most affected by these risks.

*3.2.1. Effects of climate change on agricultural production*

Climate variability, through its various manifestations, has repercussions on the livelihoods of households that are heavily dependent on the climate. The availability of data from 1985 to 2015 would have been useful for refining the analyses of these effects.

Agriculture remains a sector highly vulnerable to climate change. This is due to its predominantly rain-fed nature. The effects are varied and increasingly concerning. Climate change impacts both flora and fauna. Current weather conditions are believed to favor the proliferation of certain animal species (according to 85% of survey respondents), but also the proliferation and decline of certain plant species (according to 60% of survey respondents).

Indeed, in inter-seasonal conditions, the impact of the thermo-hygrometric couple on the population dynamics of pests is high when the following conditions are met: a long season; both factors (temperature and relative humidity) sufficiently high and respectively low high temperature extremes and relatively low humidity extremes for a long period during the dry season (P. Atachi, 2006, p.29).

### 3.3. Cultivation techniques

Farming techniques best characterize agriculture, as the quality, quantity, and even range of products obtained depend on their effectiveness and efficiency. They reflect the agronomic properties of the soil and land tenure within the region. These innovations vary according to the sociocultural groups present. Table II above highlights farming practices according to the ethnic groups in the study area.

**Table 2** Highlighting agricultural practices according to ethnic groups in the study area

| Sociocultural groups | Technical |
|---|---|
| Otammari | Controlled burning-clearing-plowing-sowing |
| Betamaribe | Land clearing-slash burning-plowing-sowing |
| Adja | Land clearing-slash burning-plowing-sowing |
| Fon | Clearing-slash-burning-plowing-sowing-slash-burning-plowing |
| Mahi | Land clearing-slash burning-plowing-sowing |

Source :Survey results, March-April 2006

Analysis of this table reveals that each farming practice has distinct advantages. Among the Cabiè, trees are cut down during the dry season. This method saves time during the rainy season. This farming practice appears to be the same among the Bêtamaribè. The Adja, Fon, and Mahi ethnic groups use the same farming practices and take into account the variability of the rainy seasons. The types of crop associations and rotations are listed in Table III below.

**Table 3** Crop rotation and association in the study area

| Socio-cultural groups | Among agricultural migrants | | | |
|---|---|---|---|---|
| | ***1st year*** | ***2nd year*** | ***3rd year*** | ***4th year*** |
| **Otammari**<br>**Betamaribe**<br>**Adja**<br>**Fon** | IHGR-Mn-P<br>IHGR-Mn<br>MIHA<br>IMHA | MS-Se-C<br>MHSC<br>MHA-Mn<br>CMH-Mn | SHAC<br>PGI<br>M-Mn<br>M-Mn | THAT<br>Mn-A<br>Mn |
| Mahi | Among the natives | | | |
| | IVM-Pt-C | VPC-Mn | M-Mn-HA | MA-Mn |

Source :Survey results, April 2006

I = Yam; H = Bean; G = Okra; R = Rice; Mn = Cassava; P = Chili pepper; M = Maize; S = Sorghum; Se = Sesame; C = Cotton; A = Peanut; Pt = Plantation; V = Vouandzou

Analysis of the table reveals the same principles among both agricultural settlers and indigenous populations. Crop rotations begin with yams, followed by cereals, and this intercropping pattern remains consistent and widespread. The second year is dedicated to maize, the most demanding of the cultivated cereals.

Today, these monocultures are being adopted by Indigenous peoples, who are reducing their use of intercropping. Whether practiced in colonized or Indigenous settings, crop rotation exemplifies a high degree of agricultural sophistication. This sophistication is even more evident in the way farmers practice intercropping. It should also be noted that, within this system, the plants are carefully selected. They are sown one below the other, so that the soil remains constantly shaded and protected against erosion.

### *3.3.1. Factors in agricultural changes*

From a climatic perspective, farmers want to prepare for certain eventualities such as prolonged droughts or abundant rainfall. Indeed, farmers know that some crops tolerate these climatic variations better than others.

From a soil science perspective, farmers know that some plants are less demanding than others and thrive in poor soils. For example, cassava on poor soil yields a significant harvest, while pigeon peas regenerate poor soil. Intercropping and crop rotation have led to the introduction of new crops, primarily by immigrants. Table IV summarizes all the crops involved.

**Table 4** Some plants introduced into the environment by migrants

| **Legumes** | **Cereals** | **Tubers** | |
|---|---|---|---|
| Soy | Rice | Yam | Cassava |
| Chickpea | Sorghum | Laboko | Ahotonon |
| Dohi | | Clatchi | Odogbo |
| Cowpea | | Yindou | |
| | | Satchin | |

Source :Results of Field Surveys, March 2006

Analysis of this table shows that the introduced crops are legumes, tubers, and cereals. Chickpea cultivation is endemic to the study area. The majority of tubers, especially yams, which have a considerable yield, were introduced by migrants.

### *3.3.2. Aricultural calendar*

The agricultural calendar generally begins in February with the preparation, using fire, of the sowing of maize and other cereals and ends in January with the planting of yams.

Field preparation typically lasts around three months (February, March, and April) for most crops. However, yam field preparation takes place between July and the end of October at the latest. This period often coincides with the harvest of other crops such as beans and maize. Maintenance work extends from May to the end of September or even the beginning of October. The busiest period in the agricultural calendar is between August and the end of November or the beginning of December. This is when farmers are overwhelmed by harvesting and preparing their yam fields.

This time is dreaded by farmers and coincides with the period of full employment in the villages. Agricultural workers are in high demand for the work. The details of all this work are described in the table below.

**Table 5** Description of the annual agricultural activities in the Aklampa District

| Month / Activities | Jan | Feb | March | April | May | June | Jul | August | Seven | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yam | ♠ | • | ◊ | ◊ | ◊ | | ♥ | ♥Δ | Δ | Δ | Δ | ▲ |
| But | • | ♂ | ♂ | ♂♣ | ◊ | | ◊ | ◊▲ | ▲ | | | |
| Cotton | ▲ | | | | | ♣ | ♣ | ◊ | | ◊ | ▲ | ▲ |
| Peanut | | ♂ | ♂ | ♂♣ | ◊ | | ♂▲ | ♂♣ | ♣ | | | ▲ |
| Bean | | ♂ | ♂ | ♂♣ | ◊ | | ▲ | ▲ | | | | |
| Cashew Teak | | ▲ | ▲ | ▲ | | ♣ | ♣ | ♣ | | | | |

Source :Results of field surveys January 2006; Legend: ♥ = Clearing period ◊ = Weeding period; Δ = Mound formation period ♂ = Cleaning period; ♣ = Sowing and planting period ▲ = Harvest period

Observing this table reveals the existence of two distinct periods. The busiest period runs from August to December, coinciding with harvest time. The less busy period, from January to March, corresponds to soil preparation. Ultimately, the farmer lacks sufficient rest, which inevitably impacts his health, given the arduous nature of fieldwork.

Agricultural activities follow a closed cycle, especially in colonial settings, because there is no distinct break between the harvests, which mark the end of the agricultural season, and the preparation of the fields, which signals the beginning of another season. This situation is explained by the fact that settlers came for economic reasons. The agricultural calendar also contributes to increased production. This is reflected in the growth of cultivated areas, increased production, and the interest shown by merchants in the immigrants.

### 3.4. Dynamics of land use

This section aims to show the extent of the damage caused by the establishment of crops, transhumance and the exploitation of wood products (figures 7 and 8).

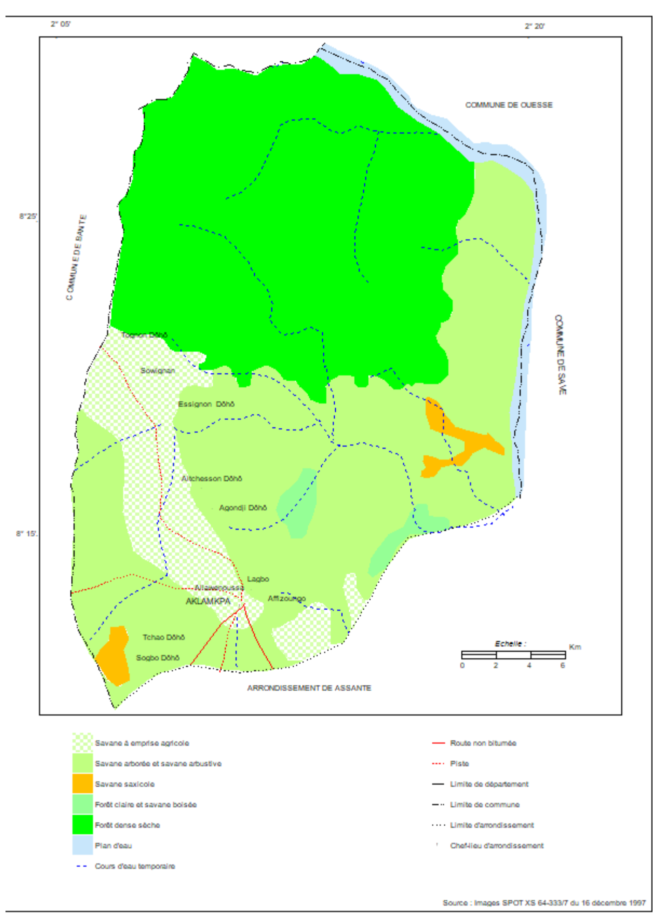



**Figure 7** Land use in the Hills Department in 1997

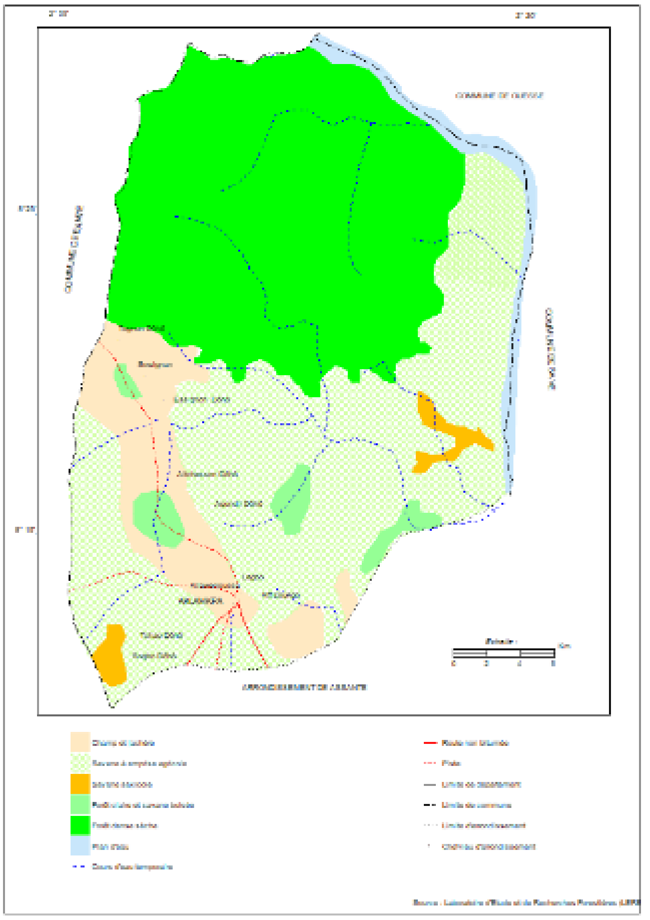


**Figure 8** Land use in the Hills Department in 2006

Observations of the 1997 map of the study area reveal a trend toward the expansion of fields and fallow land, agricultural savannas, and human settlements (farms, hamlets, and villages). During this same period, a considerable decline in forest stands within wooded and shrubby savannas is observed. This decline is reflected in the transformation of forest stands and wooded savannas into shrubby savannas and is likely due to the activities of logging companies established in the area for timber harvesting, charcoal production, and grazing. The expansion of savannas for agricultural purposes, fallow land and fields, as well as settlements, is explained by demographic trends and agricultural colonization. Indeed, the natural increase in the local population and even the low level of development contribute to the expansion of villages over time and space.

*3.4.1. Land use in the Collines department (1997 and 2006)*

Table VI allows us to appreciate the evolution of the surface area of the different land use units in the department of the hills.

**Table 6** Land use units

| Occupancy units | State in 1997 | | State in 2006 | | Balance sheet |
|---|---|---|---|---|---|
| | Area (ha) | (%) | Area (ha) | (%) | (%) |
| Dense dry forest | 32862.3 | 39 | 32398.6 | 38.6 | -0.4 |
| Open forests and wooded savannas | 2585.91 | 3 | 1229.13 | 1.5 | -1.5 |
| Wooded and shrubby savannas | 35971.09 | 43 | 0 | 0 | 0 |
| Saxicolous vegetation | 1158.40 | 1 | 1158.40 | 1 | 0 |
| Savannah with agricultural use | 7325.47 | 9 | 37783.29 | 44.9 | +35.9 |
| Mosaic of crops and fallow land | 1560.76 | 2 | 8894.51 | 11 | +9 |
| Body of water | 2567.07 | 3 | 2567.07 | 3 | 0 |
| **Total** | **84031** | **100** | **84031** | **100** | **+42.6** |

Source :Results of cartographic processing (land cover map from 1997 and 2006)

The Hills Department covers an area of84,031 haThere is a noticeable trend towards an increase in savannas under agricultural use and in mosaics of crops and fallow land. Their areas are increasing respectively from7325.47 hathat is, 9% of the portion of the study in 199737783.29 harepresenting 44.9% of the study area in 2006. Observation reveals a growth rate from 1997 to 2006 of 415.78%. As for the mosaics of crops and fallow land, their areas increased from1560.76 hai.e. 2% of the study portion in 19978894.51 hain 2006 with a rate of change (1997-2006) of 469.88%.

**Table 7** Gives a summary of the rates of change of land cover units

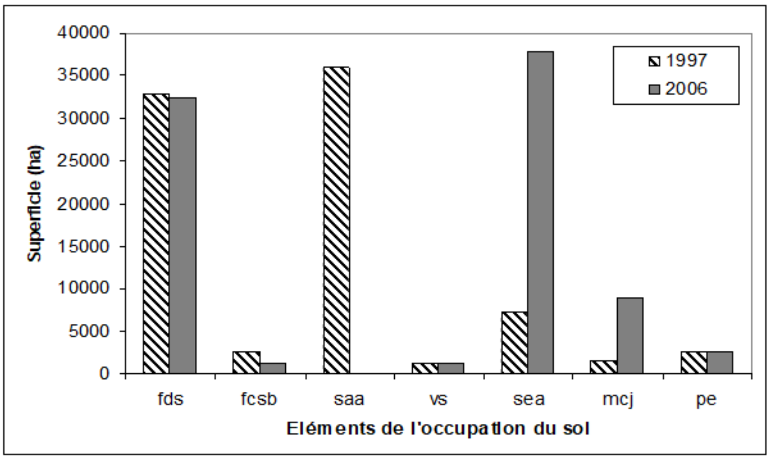
| Indicators / Land use units | 1997 | 2006 | Rate of change 1997-2006 (%) | Annual growth rate | Observation |
|---|---|---|---|---|---|
| *Dense dry forest* | 32862.30 | 32398.60 | -1.41 | -0.14 | Slight regression |
| *Open forests and wooded savannas* | 2585.91 | 1229.13 | -52.47 | -5.25 | sharp decline |
| *Wooded and shrubby savannas* | 35971.09 | 0.00 | -100.00 | -10.00 | sharp decline |
| *Saxicolous vegetation* | 1158.40 | 1158.40 | 0.00 | 0.00 | Stability |
| *Savannah with agricultural use* | 7325.47 | 37783.29 | 415.78 | 41.58 | Strong progress |
| *Mosaic of crops and fallow land* | 1560.76 | 8894.51 | 469.88 | 46.99 | Strong progress |
| *Body of water* | 2567.07 | 2567.07 | 0.00 | 0.00 | Stability |

Source :Land use maps from 1997 and 2006

The progression is then strong with an annual rate of change of 41.58 for open shrub savannas and 46.99 for mosaics of crops and fallow land.

The other formations experienced a decrease or regression, sometimes strong and sometimes weak, with some cases of stability.

Observation of the tables generally reveals a decline in dense vegetation formations: gallery forests, open woodlands, wooded savannas, deciduous forests, as well as tree and shrub savannas. The evolution of the surface areas of these formations is shown in Figure 9.




Legend :Fcsb = open forest wooded savanna, fds = dense dry forest, Saa = shrubby wooded savanna, Sea = savanna with agricultural use, pe = body of water, mcj = mosaic of crops and fallow land, VS = saxicolous vegetation.

**Figure 9** Changes in the surface area of different land use units in the Collines department in 1997 and 2006

Analysis of this figure shows that the areas of dense formations are undergoing a significant regression. When considering the map with its total area (84031 ha) the dense formations have gone from32862.3 ha(39%) in 199732398.6 ha(38.6%) in 2006.

### 3.5. Rural migrations and environmental impact

Assessing the impacts of development actions on the environment is a fundamental impact for forward-looking management of natural resources.

#### *3.5.1. Farming systems and environmental degradation*

Similar to what is observed in agriculture in tropical regions with limited land, in the Collines Department, farmers are opting for extensive agriculture with the practice of fallowing. This practice of expanding farming systems is implemented by immigrants from both the north and the south. This extensive approach to farming systems is dangerously impacting the land in the study area.

#### *3.5.2. General observation on the level of environmental degradation*

Agriculture is the activity that occupies the most land. Indeed, shifting cultivation based on fallow periods is a common technique given the abundance of arable land in the study area. Populations move when crop yields become low. This movement allows the soil to regenerate and regain its fertility through the growth of natural vegetation. However, the existence or increasing prevalence of fallow land is noted in the region. The reality is that fallow land is expanding throughout the area.

#### *3.5.3. Evolution of the agricultural potential of the Collines department*

Taking into account the statements of indigenous populations, some NGO officials, ATDA agents, and the work of Tchégnon (1995), Sounon (1995), and Chabi (1997), it can be concluded that the exploitation of immigrants, particularly the Fon, Bêtamaribè, Lokpa, and Daatcha, to name just a few, generally causes serious damage to the soil and the environment. Investigations have revealed that in the Collines department, Fon farmers, after three years of cultivating a plot of land, abandon it for a new one. The immediate consequence is that a vast area is destroyed in a short period.

In addition to agricultural production, they are charcoal producers and harvesters of timber and firewood. These various activities allow them to strip the soil bare, leaving only herbaceous vegetation.

## 4. Conclusion

The farming community faces enormous difficulties in carrying out its agricultural activities. Among these are the problems caused by climate change. Based on feedback from farmers in the study area, it can be said that poor rainfall distribution, delayed start to the rainy season, pockets of drought during the rainy season, strong winds, and excessive heat are the elements that have characterized the climate for the past forty (40) years. This climate variability has significant consequences for the environment and the daily lives of farmers. The impact of climate variability on farmers' daily lives is reflected in decreased yields, crop losses, and the resurgence of certain diseases (anemia and diarrheal diseases in humans). This study demonstrates how agriculture and human well-being are adversely affected by climate variability in the study area. Crop yields have continually declined, production has been severely affected lately, agricultural prices have increased, and cereal consumption is falling, resulting in decreased calorie absorption and increased child malnutrition.

To mitigate the effects of climate variability, agricultural producers are developing strategies that draw on both local and external knowledge. The alarming nature of climate change, particularly in developing countries, is a significant factor motivating continued research in this area.

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