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# Land use dynamics and socio-economic impacts of wetlands in the Oti plain in the face of climate change

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***Abstract*— *Wetlands are one of Togo's most important natural resources. However, human pressures on these already vulnerable environments are contributing to a reduction in their surface area and, consequently, to a loss of biodiversity. The aim of this study is to assess the vulnerability of wetlands to climate change through a diachronic analysis of changes in climatic parameters over the period 1970-2021. To do this, we first mapped land use units from 1987 to 2019 in order to identify the various pressures on wetland ecosystems in the Oti plain in northern Togo (Ramsar site of the Oti-Kéran-Mandouri protected areas). Secondly, we identified wetland degradation factors and the socio-economic impacts of this degradation on local populations. The results show that the surface area of the natural land-use units of the Oti plain has declined over the last thirty years. Over the same period, the climate in the area has been highly variable, alternating between dry and wet periods, with a general trend towards lower rainfall and higher temperatures. The effects of this climate change, coupled with human-induced degradation factors, are having a negative impact on the socio-economic situation of local populations. The Participatory Analysis of Powerty and Livelihood Dynamic (PAPOLD) also enabled farmers to be classified into three prosperity classes (Poor, Moderately Well Off and Well Off). The results provide a decision-making tool for sustainable, participatory management of the wetlands of the Oti plain.*

***Keywords*— Climate change, Prosperity classes, Dynamics, Wetlands, Land use, Oti plain.**

## I. INTRODUCTION

Because of the many functions and ecosystem services they provide to mankind, wetlands have become indispensable to our existence. In addition to the fact that humans have learned to take advantage of them for livestock farming, various crops, navigation, recreation and landscaping, wetlands regulate the water and climate regime, protect the soil and drinking water, purify water and are incredible reservoirs of biodiversity (DORIANE, 2014). In Togo, and particularly in the northern part of the country, wetlands offer additional food security, which is all the more important given that rainwatered crops can fail due to drought. In fact, 62.3% of the rural population lives off natural resources in general and the resources of catchment areas and their wetlands in particular.

Despite the many goods and services they provide, wetland areas are still being degraded. The causes of this degradation are not only linked to climatic hazards, but above all to human activities. The socio-economic and ecological issues surrounding wetlands, and the conflicts they generate, mean that there is a growing need for more comprehensive management, taking into account the environments, resources and activities that develop there (DETRIEUX and al., 2000). In 1987, following the publication of the Brundtland Report by the United Nations Commission on Environment and Development, the RAMSAR Convention formalised the concept of the wise use of wetlands. The wise use of wetlands is the maintenance of their ecological character achieved through the implementation of ecosystem approaches in the context of sustainable development.

As of January 2020, four (04) sites in Togo have been included on the list of wetlands of international importance, representing a wide diversity of aquatic and terrestrial ecosystems covering almost 12,104 km2, or approximately 21% of the country's surface area. These RAMSAR sites have various protection statuses, some of which are classified as national parks and wildlife reserves (Kéran National Park and Togodo Wildlife Reserve), while others are classified as watersheds, protected areas and coastal areas (Oti-Mandouri watershed and coastal wetlands).

The Oti plain wetlands in question are the Oti-Kéran-Mandouri protected areas (OKM for short). The current dynamics of these wetlands is guided by the interaction of climatic hazards and anthropogenic factors marked by intense agricultural and pastoral activity. These wetland ecosystems are also used for internal population movements to conquer good land for agricultural purposes, which is highly coveted by various stakeholders such as farmers, fishermen, livestock breeders and loggers. Wetlands and other land-use units in these ecosystems are being degraded, making them highly vulnerable. This degradation is not without consequences for the socio-economic status of local populations. As a result, when these wetlands are degraded, the services they provide to humanity are reduced, with negative socio-economic consequences for rural communities in particular, who have no other source of income.

Several wetland management strategies have been initiated over the last thirty years. Among these strategies, the people-centred approach developed by WOOD et al (2013) seems to be the most appropriate. This approach considers populations as active managers-users (natural resources), and not as conservation managers.

Many scientific studies on wetlands have been carried out in Togo. These studies have focused on plant species and degradation factors, and have paid little attention to the land-use dynamics of wetlands over the past thirty years. The present study, which falls within this framework, was carried out to add to the existing literature. Our approach consisted firstly of a diachronic analysis, which enabled us to understand the evolution of land-use units, then we analysed the evolution of climatic parameters over the period 1975-2021. The study ended with a review of wetland degradation factors and an assessment of the socio-economic impact using the PAPOLD method.

The results obtained constitute a decision-making tool for the development and implementation of protection, conservation and development measures for natural ecosystems such as wetlands.

## II. MATERIALS AND METHODS

2.1 Presentation of the study environment

The Oti plain, our study area, is a wetland located in the northern region of Togo, extending between latitudes N 9°30' and N 11°00' and longitudes E 0°15' and E 0°55'. It is a sub-unit of the greater Volta basin (Fig 1). It is located in ecological zone I (ERN, 1979), which corresponds to the northern plains covered mainly by dry Leguminoseae and Combretaceae savannahs, harbouring significant biological diversity (KOUMANTIGA and al., 2018; BADABATE and al., 2012) and a hydrographic network that drains the entire plain. The Oti is the major river, and its tributaries, the Kéran, Koumongou, Kara, etc., are the main watercourses. The Oti plain is a vast peneplain that experiences major seasonal flooding between September and October. It is a biodiversity sanctuary that provides ecosystem

goods and services to the local population, most of whom live in rural areas. It covers the protected areas of the Oti-Keran/Oti-Mandouri (OKM) complex, covering an area of 179,000 ha straddling four prefectures, three of which are located in the Savannah region: Oti-North, Oti-South and Kpendjal prefectures, and the other in the Kara region: Kéran prefecture. The protected areas of the OKM complex have been classified as a RAMSAR site since 2007 and recognised as a Biosphere Reserve by the UNESCO MAB Commission in 2011 (KOUMANTIGA and al, 2018).

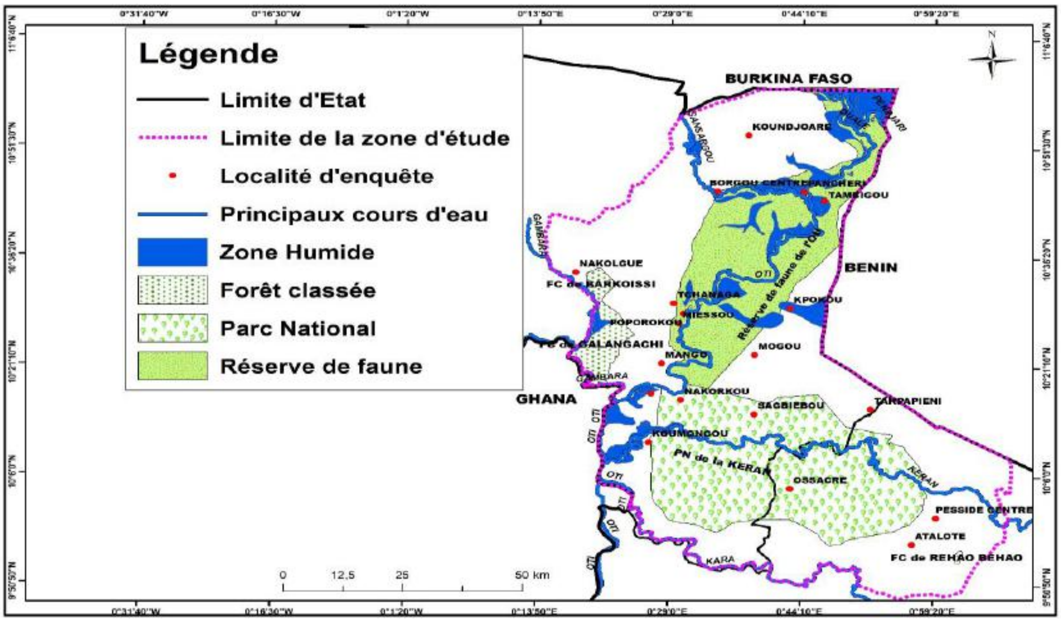



*Fig.1 : Map of the study area*

**1.2 Methodological approach and data collection tools**

**1.2.1 Spatial analysis of land use in the wetlands of the Oti plain between 1987 and 2019**

The cartographic approach is based on a diachronic study of land-use maps of the Oti plain between 1987 and 2019. In order to assess the dynamics of landscape change and land use in the wetlands of the Oti plain, a spatial analysis of land use was carried out. This spatial analysis was carried out using Landsat 8 images with high spectral resolution and Google Eart.

➢ **Image processing tools**

Image processing, GIS and statistical analysis tools were used. These tools are :

- ERDAS Imagine 2011 and Leica Geosystems Geospatial Imaging software for digital image processing, radiometric and geometric corrections, band assembly, mosaicking and supervised image classification;
- ArcGIS and ENVI software for map production;
- Excel spreadsheet for graphical representation of statistics extracted from cartographic results, conversion and import.

➢ **Processing satellite images**

The study of the dynamics of land use in the wetlands of the Oti plain over the period 1987-2019 consisted firstly of a supervised classification of each satellite image. The classifications were then followed by a pixel-by-pixel change detection analysis to identify and correct unlikely trajectories. Once these images had been classified and corrected, the quality of the post-processing was finally assessed in order to validate or not the corrections made.

➢ **Diachronic analysis of land use between 1987 and 2019**

Once the land cover maps for 1987 (T1) and 2019 (T2) had been drawn up, a comparative analysis of the two states T1 and T2 was carried out by calculating the Rate of Expansion (Δ) given by the formula proposed by the Food and Agriculture Organization (FAO) in 1996

(Ecological Monitoring Centre et al., 2012): $\Delta = S1 - S2$ where S1 and S2 represent respectively the percentage proportion of the area of a land cover class in the most recent year and the oldest year.

If: $\Delta = 0$ then there is stability (S);

$\Delta > 0$ then there is progressive change (P);

$\Delta < 0$ then there is regression (R).

This method was used to assess the evolution of the different land cover units from 1987 to 2019 and to determine the different orders of regression (1, 2, 3, ...n), progression (1, 2, 3, ...n) and stability, since dynamics reflect the effects of population activities on the vegetation cover. Using the formula proposed by the FAO (1995), which is widely used (HOANG and al., 2002; NOYOLA-MEDRANO, 2006; PUYRAVAUD, 2003; SPARFEL, 2012; OLOUKOI, 2013; Brun and al., 2018), the balance (T) is calculated by the formula: $T = (1/(t2-t1)) \times \ln(S2 / S1)$.

where S1 and S2 correspond respectively to the area of a land cover category in year t1 and year t2; T is the number of years of change (balance); ln is the natural logarithm.

### 1.2.1 Climatic vulnerability of the Oti plain wetlands: rainfall and temperature

Climatological data such as temperature and rainfall from 1970 to 2021, either 50 years, have been taken into account in the analysis of this climatic vulnerability; this is to comply with WHO (1980) requirements according to which a minimum of 30 years is needed for a valid study of climate change (BADJANA and al., 2011). The diachronic analysis of changes in these two climatic parameters in the region over the time periods 1970-1995 and 1996-2021 enabled us to assess the trends in these parameters over 50 years and their impacts on the wetlands of the Oti plain. This analysis was based on rainfall and temperature data from the synoptic stations at Mango, Dapaong and Niamtougou.

### 1.2.2 Anthropogenic factors in the degradation of Oti wetlands

In order to study the relationship between the wetlands and the anthropogenic factors (agriculture, logging, livestock farming, fishing and hunting) responsible for their degradation, surveys and field trips were carried out among the target groups selected for this purpose.

Socio-economic data was collected on the basis of survey sheets using direct and semi-direct interview techniques, interview guides and focus groups.

- Sampling technique

The random selection method was adopted as the sampling technique. Given the specific nature of the wetlands in the study area, the localities surveyed were selected taking into account 03 factors: their spatial distribution in the study area, the presence of human activities that degrade the wetlands and also the strategic position that wetlands occupy in socio-economic activities**.** Three localities were surveyed. These were Tchanaga, Sadori and Péssidè.

In these localities, the stakeholders taken into account in the survey are: farmers, stockbreeders, hunters, fishermen and loggers. The people interviewed were aged between 35 and 50, and their activities had a direct influence on the wetland ecosystems. A total of 135 people were surveyed in all three localities. Table 1 below shows the spatial distribution of the people surveyed by sector of activity.

*Table 1: Spatial distribution of respondents by sector of activity.*

| Locations surveyed | Sectors of activities surveyed | Workforce by business sector | Total workforce by location |
|---|---|---|---|
| Tchanaga | Farmers | 15 | 40 |
| | Breeders | 8 | |
| | Fishermen | 7 | |
| | Hunters | 5 | |
| | Foresters | 5 | |
| | | | |
| Sadori | Farmers | 20 | 50 |
| | Breeders | 10 | |
| | Fishermen | 10 | |
| | Hunters | 5 | |
| | Foresters | 5 | |
| | | | |
| Péssidè | Farmers | 20 | 45 |
| | Breeders | 10 | |
| | Fishermen | 5 | |
| | Hunters | 5 | |
| | Foresters | 5 | |
| TOTAL | | | 135 |

- **Processing of socio-economic data**

The survey data were processed using Kobocollect and Excel 2013 software. Based on this processing, the factors causing wetland ecosystem degradation in the various localities were identified.

**2.2.4 Assessment of the socio-economic impacts of wetland degradation on local populations**

The socio-economic impacts of wetland degradation on local populations were assessed using the PAPOLD method (Participatory Analysis of Poverty and Livelihood Dynamics). This method is based on a technique called "Stages of Progress", which was developed by Prof. Anirudh Krishna of Duke University in the United States to obtain the local community's conceptions of poverty, prosperity and the phases through which households could emerge from their extreme poverty and become prosperous (KALINGANIRE and al, 2005). For this assessment, three categories of producers were taken into account because of their direct influence on the wetlands. These were farmers, livestock breeders and fishermen in the three localities surveyed.

The first step was to get the producers to identify the criteria for prosperity in the local terms of Poor or Deprived, Moderately Well Off, Well Off. To do this, we asked key questions such as: what are the most important goods for a young farmer setting up in business, and what are the priority needs to be met as his means increase? What are the minimum needs of the poorest farmer in the village?

People are capable of listing these goods and needs, which constitute the criteria for prosperity. We had to reach a consensus on the order of the criteria and number them. In this way, all the prosperity criteria for the locality were ranked and we proceeded to draw the poverty line and the prosperity line.

We considered two different periods chosen by the people themselves in order to study the dynamics of poverty. The choice of each period was dictated by an event that had marked the locality, such as starvation, flooding, drought, etc.

The socio-economic data obtained using the "PAPoLD" method was entered in tabular form using Excel 2013 software. The various prosperity criteria selected for all three localities were codified and then harmonised using the formula below: $\mathbf{Y_i = (n_i\text{-}1)/ (N_i\text{-}1)}$ where ni: the value of the criterion in locality; Ni: the total number of criteria cited in locality.

To take account of the fact that the number of criteria in the three localities is not the same, the prosperity classes for all the localities were normalised using the formula : $\mathbf{M_i = \sum Y_i/4}$ with $\mathbf{Y_i = (n\text{-}1)/ (N\text{-}1)}$.

**Movements in household poverty and the magnitude of the movement**

The movement in poverty was measured by comparing the level of prosperity of the producer in 2002 and that in 2022. To do this, 4 classes were defined using the PAPOLD method:

- A: poor in 2002 and still poor in 2022
- B: poor in 2002 and not poor in 2022
- C: non-poor in 2002 and poor in 2022
- D: not poor in 2002 and still not poor in 2022

A class was assigned to each producer according to their situation.

Movements in poverty were assessed by calculating the percentage of prosperity classes (Deprived, Moderately Well Off, and Well Off) and poverty movement classes (A, B, C, and D), for all four localities from 2002 to 2022. Similarly, the prosperity classes according to poverty movements were determined by percentage calculations.

Based on the two prosperity levels in 2002 and 2022 and the prosperity movement class, we can assess the magnitude of the prosperity movement. This can be positive, negative or zero. It is used to classify producers. The magnitude of poverty movements was determined by calculating the difference between the 2022 prosperity class and that of the historical year used in the locality.

## III. RESULTS

**3.1 Spatial analysis of land use in the wetlands of the Oti plain between 1987 and 2019**

Spatial analysis of the land-use change map (Fig. 2) of the wetlands between 1987 and 2019 shows that the hierarchy of land-use types has remained the same, but the relative importance of the units has varied over time.

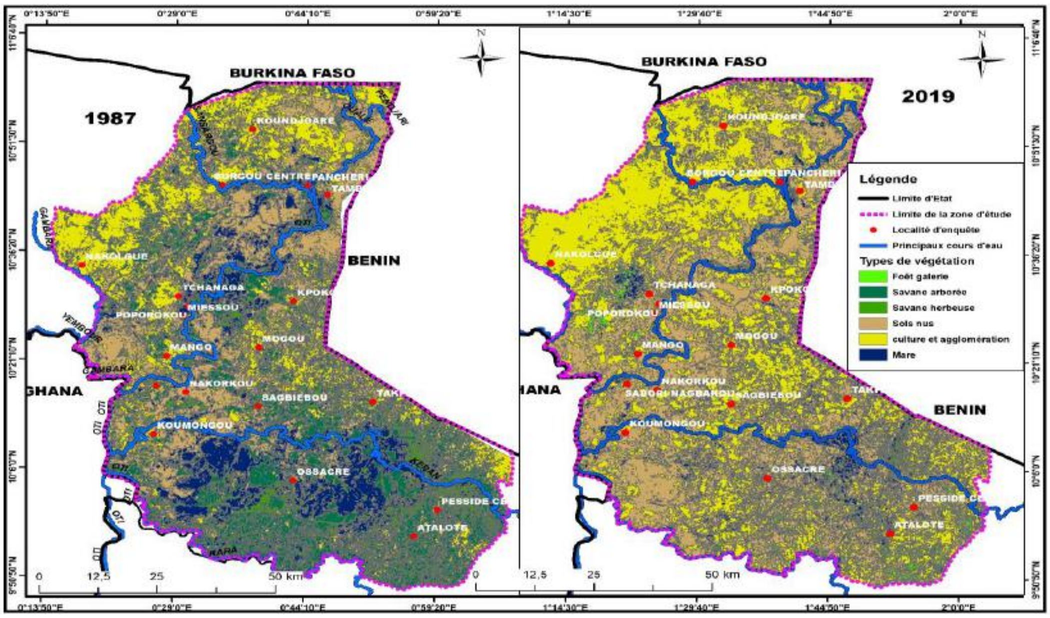



*Fig. 2: Land use in the wetlands of the Oti plain between 1987 and 2019.*

Examination of Figure 2 shows that from 1987 to 2019, land-use units have changed in time and space. For example, ponds and swamps, gallery forest, wooded savannah and grassy savannah have declined in favour of bare soil and cultivated and built-up areas. This explains the various pressures that these formations are subject to from man.

- **Evolution of wetland land use units between 1987 and 2019**

In 1987, the land-use units of the Oti plain were dominated by wooded savannah, which occupied 25% of the total surface area; bare soil, crops and settlements covered 23%. Ponds and swamps accounted for 13%, while grassy savannahs made up 9% of the total wetland area. The remaining 1% was gallery forest (Table 2).

*Table 2: Change in hectare area of land use units from 1987 to 2019.*

| Occupancy units | 1987 | | 2019 | | Expansion rate Δ |
|---|---|---|---|---|---|
| | Surface area in Ha | Proportion in % | Surface area in Ha | Proportion (%) | Δ = S2019-S1987 in % |
| Bare floors | 171792,15 | 23,34 | 296739,14 | 40,32 | 16,98 |
| ponds and swamps | 132310,98 | 18,00 | 55990,60 | 7,61 | -10,39 |
| Cultures and urban areas | 171098,75 | 23,24 | 352780,63 | 47,93 | 24,69 |
| Gallery forest | 7776,50 | 1,00 | 6233,56 | 0,85 | -0,15 |
| Wooded savannah | 183686,71 | 25,00 | 14876,00 | 2,02 | -22,98 |
| Grassy savannah | 69333,74 | 9,42 | 9378,91 | 1,27 | -8,15 |
| Total | 735998,84 | 100,00 | 735998,84 | 100,00 | ------- |

Analysis of Table 2 shows that in 2019, wooded savannah has completely regressed, falling from 25% of the total area in 1987 to 2% in 2019, i.e. a rate of expansion of -22.98%. At the same time, grassy savannah, ponds and swamps have also declined, from almost 10% of the total area to 1.27% for grassy savannah and from 18% of the total cover to almost 8% for ponds and swamps. Forest galleries, which occupied 1% of the total surface area in 1987, have also declined, representing just 0.85% of the total surface area in 2019, with an expansion rate of -0.15%. However, there has been a significant increase in bare land, crops and built-up areas. The area of bare land rose from 23.34% to 40% between 1987 and 2019. The area under crops and built-up areas rose from around 23% to almost 48% between 1987 and 2019.

This analysis shows that the trend in land use units is positive overall for man-made formations, with positive expansion rates, while it is regressive for natural vegetation formations, with negative expansion rates (Fig 3).

The extent of the changes observed is a consequence of the strong human pressures leading to growing needs for arable land and the uncontrolled exploitation of the natural resources of the wetlands of the Oti plain.

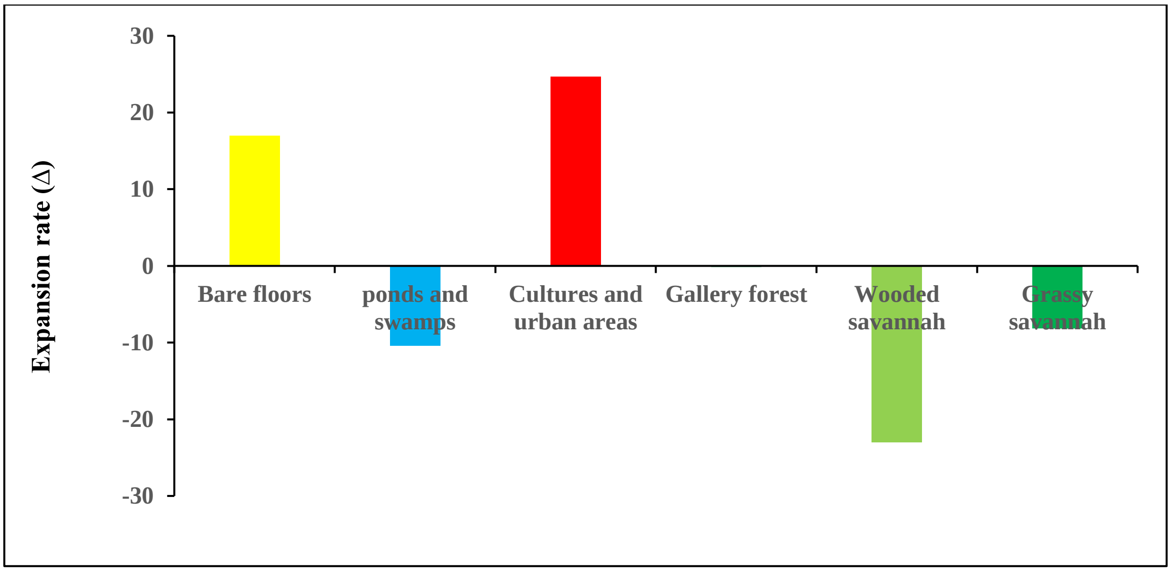



*Fig. 3: Evolution of the expansion rate of land cover classes.*

- **Assessment of the dynamics of land use in wetlands between 1987 and 2019**

The spatio-temporal dynamics of land use units in the wetlands of the Oti plain is expressed in terms of:

- Stability: it takes into account the portions which, apparently, have not experienced pronounced changes or at least have kept the same appearance between 1987 and 2019. The dynamics of occupation reveals that no unit has experienced stability from 1987 to 2019. All have either regressed or progressed.
- Regression: it concerns units which have experienced a deterioration or reduction in their surface area. There are three orders of regression (R1, R2 and R3). In our case, only the R1 regression was observed and relates to the portions having undergone very pronounced degradation. This is the case for units such as: ponds and swamps, gallery forest, tree savannah and grassy savannah. These units are gradually transformed either into agricultural fields (crops), or into towns or into bare soil. This demonstrates the impact of the various anthropogenic activities carried out on the components

of the humid ecosystems of the Oti plain.

- Progression: it applies to units which have evolved to become denser in 2019 compared to 1987. There are also three orders of progression (P1, P2 and P3). In the present case, an order of progression (P3) was observed. It takes into account the units of wooded and grassy savannahs, ponds and swamps and part of the gallery forests in 1987, which are gradually being transformed into agricultural fields, towns and bare soils in 2019.

Figure 4 below presents the summary in area of the different land use units in the Oti plain.

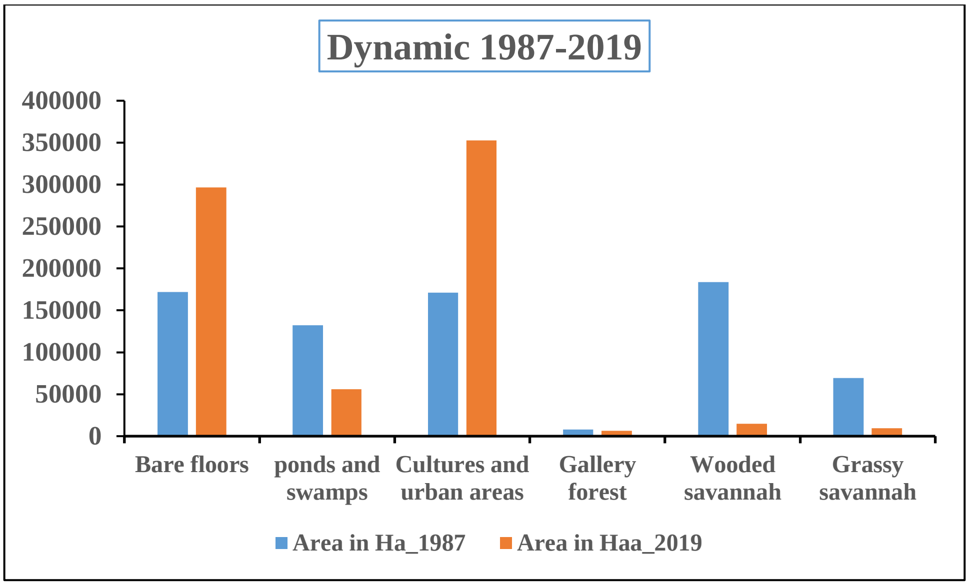



*Fig. 4: Variation in the evolution of the surface areas of land use units (1987-2019).*

*Source: Data processing results, 2023.*

### 3.2 Climatic vulnerabilities of the wetlands of the Oti plain: precipitation and temperature

➢ **Climate change in Togo**

As a West African country, Togo's climate is warming globally, with an increase in average temperatures ranging from 0.8°C to 1.2°C between 1961 and 2018 (CNCC, 2022). In addition, the National Climate Change Adaptation Plan (PNACC) indicates that between 1962 and 2012, the climate warmed by 1°C compared with previous periods. The general temperature has risen throughout the country. Other aspects of the climate have also changed, such as rainfall. Annual rainfall has fallen by between 3 mm and 81 mm (PNACC, 2017, p.18). The risk of the climate drying out is growing all the time, as rainy periods are no longer long enough to compensate for the evaporation of water from the soil, especially in northern Togo, the region covering our study area, which is close to the Sahelian zone. Also, the climate change scenarios for Togo drawn up by the PNACC predict that there could be a rise in average temperature ranging from 0.9 to 4.5°C. In the coming years, if the climate evolves as it is currently happening, Togo will have to face various climate risks such as floods, droughts, extreme heat, irregularities in the seasons, rainfall shifts, more violent winds, major soil erosion (the Savanes Region is already experiencing all these elements but they will be amplified), and finally, landslides and a rise in sea levels (PNACC, 2017, p.19).

➢ **Spatio-temporal evolution of climatic parameters in the region covering the wetlands of the Oti plain by time intervals 1975-1995 and 1996-2021**

- **Spatio-temporal evolution of temperatures.**

The Spatio-temporal evolution of temperatures in the study area over a quarter of a century can be seen by studying the isotherm maps shown in Figure 5.

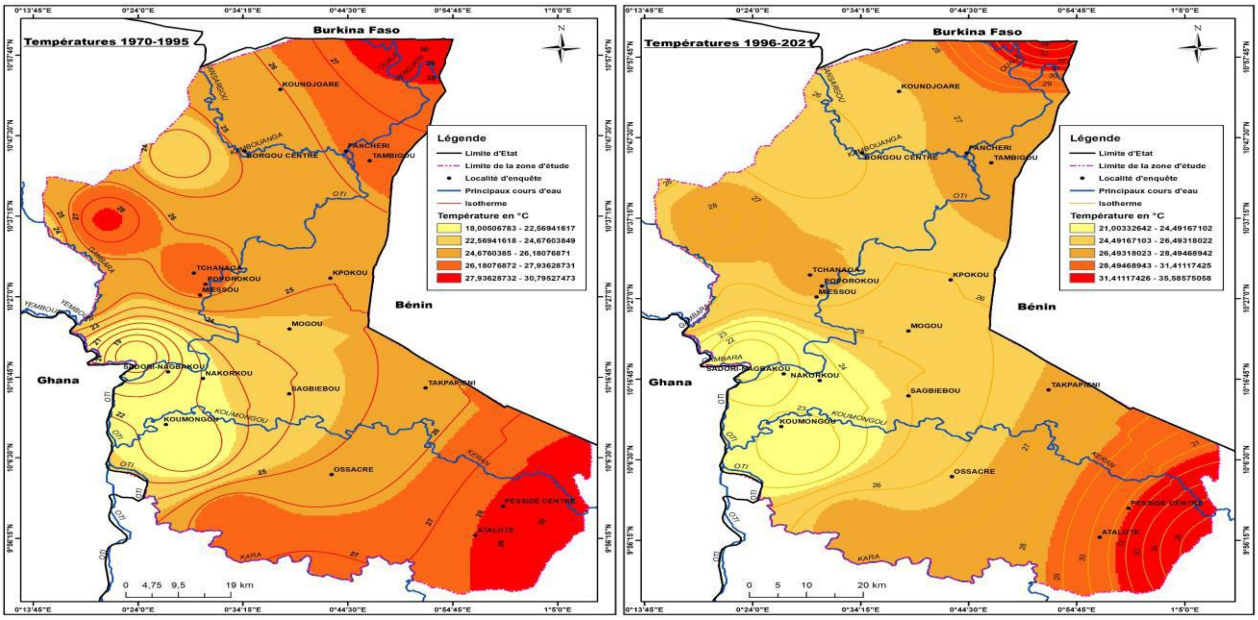



*Fig.5 : Isotherms of the average annual temperature over twenty-five years in the region of the study area*

Analysis of Figure 5 shows that, overall, average temperatures have risen over the last half-century (1970-2021). The period 1970-1995 is the warmest, with temperatures around 22°C, limited by the 23°C isotherm. Beyond this isotherm, temperatures rise towards the south-east and north-west, reaching 30°C. The maximum temperature is 30.5°C in the Pendjari area towards Mandouri.

Over the period 1996-2021, temperatures are around 24°C, limited by the 25°C isotherm, and the Pendjari and Kantè areas reach 35°C, indicating a warmer climate than in the previous twenty-five years. In fact, temperatures have risen by around 1°C.

- **Spatio-temporal evolution of precipitation**

The spatio-temporal evolution of rainfall in the study area over a quarter of a century is shown by studying the isohyet maps presented in Figure 6.

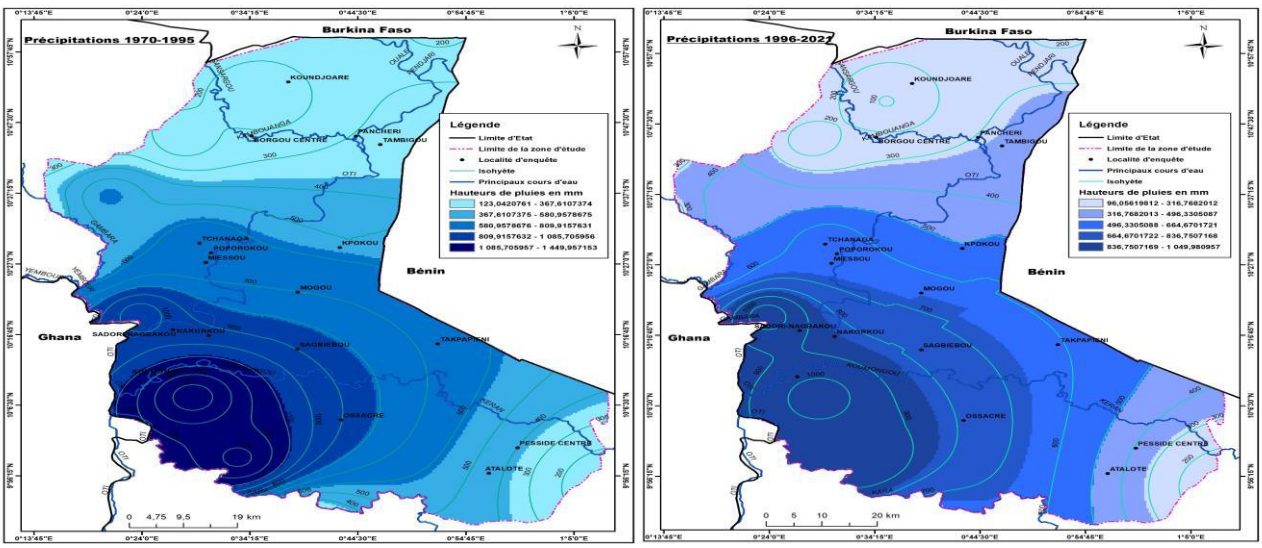



*Fig.6: Isohyets average annual precipitation over twenty-five years in the region of the study area*

Analysis of Figure 6 shows that rainfall has fallen over the last five decades (1970-2019). The period 1970-1995 was marked by significant inter-annual fluctuations, with rainfall of around 1,400 mm limited by the 1,100 mm isohyet. Above this isohyet, rainfall decreases towards the south-east and north-west to 200 mm. Maximum rainfall is 1,450 mm at Koumongou.

Over the period 1996-2021, rainfall is around 1,000 mm, limited by the 800 mm isohyet, and Koumongou reaches 1,050 mm. This reflects a drop in rainfall of around 400 mm in less than 30 years, accompanied by a migration of the 1400 isohyet towards the south of the country.

### 3.3 Anthropogenic factors in the degradation of Oti wetlands

Anthropogenic factors in the degradation of Oti wetland ecosystems are activities that have a negative impact on the environmental components of wetlands. The direct determinants identified during our field trip are: agriculture, lumbering, livestock farming, hunting and fishing.

The importance of these degradation factors was assessed according to the perception of local populations (Figure 7). Analysis of this figure shows that agriculture, forestry and livestock farming are the most important factors in wetland degradation. Agriculture, through activities such as land clearing and the use of herbicides, is leading to the gradual disappearance of natural wetland formations and, by extension, wetlands. As a result, the Oti plain is witnessing an alarming gradual degradation of its natural potential, with rich wetland forest formations disappearing in favour of bare soil and farmland. In the search for land suitable for agriculture, forest galleries are being devastated or even destroyed.

Forestry activities such as charcoal production (carbonisation) and wood energy convert natural plant formations into bare soil and agricultural land. Livestock farming is cited by the local population as a major factor in the degradation of wetland components, due to the damage caused by transhumant animals and overgrazing. In fact, the lack of grazing in Sahelian countries over a good part of the year (from December to May), the search for outlets for livestock products and the low rate at which national meat consumption is covered by local production have considerably encouraged the transhumance of Sahelian cattle to Togo. This transhumance is expanding rapidly, leading to the degradation of natural resources through the destruction of flora by tree pruning and cutting, overgrazing and the degradation of pasture and soil quality, the destruction of hydraulic structures and water pollution.

With low importance values, fishing and hunting were also seen as factors in the degradation of wetlands. Poor fishing practices, such as illegal fishing, failure to select the right species and size of fish, and the use of inappropriate techniques, lead to the over-exploitation of fishery resources and the destruction of aquatic ecosystems. As for hunting, it is perceived by local populations as a factor in the degradation of vegetation because hunters, by seeking to make game areas accessible, provoke bush fires which are powerful determinants of the degradation of wetland vegetation.

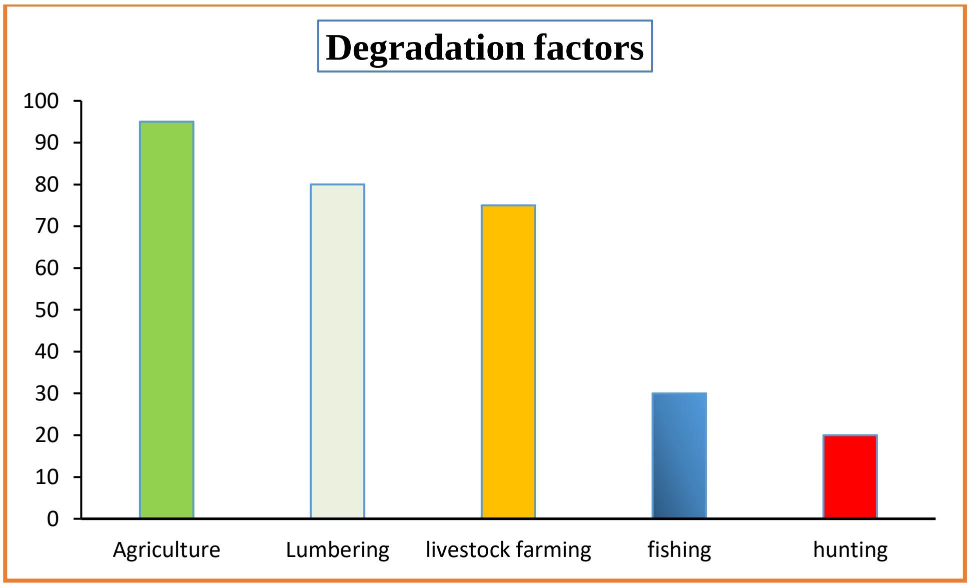



*Fig.7 : Wetland degradation factors*

**3.4 Assessment of the socio-economic impact of wetland degradation on local populations**

- **Prosperity criteria in the three localities bordering the wetlands of the Oti plain**

The prosperity criteria listed by the producers are sometimes similar, although they vary from one locality to another. In Sadori, 21 prosperity criteria were listed. The first criterion is the straw-built house. The poverty line is located at the limit of criterion 5 (small solar panel). The line of prosperity begins at criterion 12 (sheet metal house) and ends at criterion 21 (goods vehicle). This means that in Sadori, building a house made of sheet metal is a starting point for any wealthy person. The average farmer would therefore fall between the two lines of poverty and prosperity, i.e. criteria 5 and 12.

In Péssidè, 22 criteria were identified, with the poverty and prosperity lines located respectively at the limit of criterion 8 (Small solar plate) and criterion 15 (Sheet metal house). The first criterion corresponds to the daba/hoe and the last to a general food shop.

The PAPoLD revealed 22 prosperity criteria in Tchanaga, with the poverty line limited to criterion 6 (bicycle) and the prosperity line limited to criterion 13 (sheet metal house). As in Péssidè, the first criterion corresponds to a daba/hoe, while the last corresponds to a television set and a Canal+ aerial.

The different criteria listed in each locality, along with the poverty and prosperity lines, are summarised in Tables 3 and 4, Daba/hoe, poultry, plots of land and bicycle occupy more or less similar positions in the different localities, while other criteria occupy different ranks from one locality to another or are only mentioned in one of the 3 localities. Although the position and importance of each criterion varies from village to village, the criteria as a whole reflect the socio-economic realities of the three localities.

***Table** 3: Sadori and Péssidè prosperity criteria*

| *N°* | Classes | Sadori Prosperity Criteria | *N°* | Classes | Péssidè Prosperity Criteria |
|---|---|---|---|---|---|
| 1 | Destitute | Daba/hoe | 1 | Destitute | Daba/hoe |
| 2 | | Field plot | 2 | | Poultry |
| 3 | | Straw banco house | 3 | | Field plot |
| 4 | | Bike | 4 | | Straw banco house |
| 5 | | Small solar panel | 5 | | Primary education |
| | | **Poverty line (1-5)** | 6 | | Radio set |
| 6 | Moderately well off | Endure house | 7 | | Bike |
| 7 | | Electricity at home | 8 | | Small solar panel |
| 8 | | Motorbike | | | |
| 9 | | Poultry | | | **Poverty line (1-8)** |
| 10 | | Goats/Sheep | 9 | Moderately well off | House in tiled banco |
| 11 | | Solar panel | 10 | | Motorbike |
| | | **Line of prosperity (12-21)** | 11 | | Level of secondary education |
| 12 | Nantis | Sheet metal house | 12 | | Goats/Sheep/Pigs |
| 13 | | Electricity at home | 13 | | Solar panel |
| 14 | | Solar panel | 14 | | Increase in field area |
| 15 | | Motorcycle/tricycle | | | **Prosperity line (15-22)** |
| 16 | | Shop | 15 | N | Sheet metal house |
| 17 | | Goats/Sheep | 16 | | Electricity at home |
| 18 | | Steers | 17 | | Solar panel |

| | | | | | |
|---|---|---|---|---|---|
| 19 | | large agricultural area | 18 | | Motorbike |
| 20 | | Télé+ Canal+ antenna | 19 | | Large agricultural area |
| 21 | | Goods vehicle | 20 | | Goats/Sheep |
| | | | 21 | | Steers |
| | | | 22 | | General food shop |

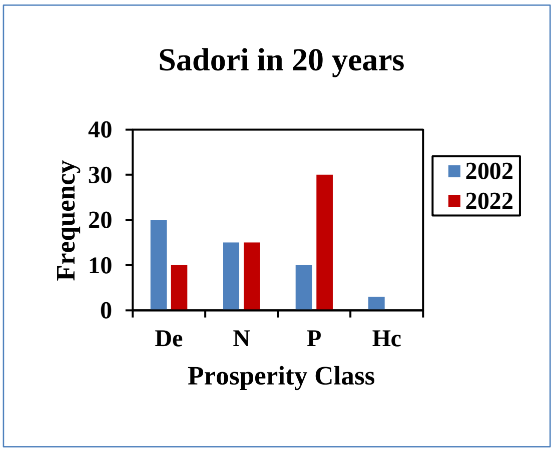
Table 4: Tchanaga prosperity criterion

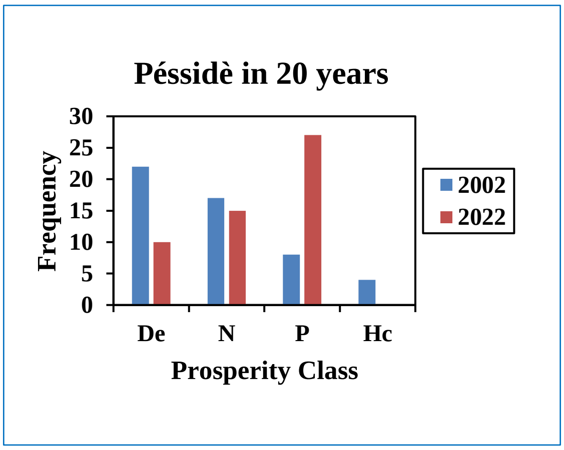
| N° | Classes | Tchanaga Prosperity Criteria |
|---|---|---|
| 1 | Destitute | Daba/hoe |
| 2 | | Poultry |
| 3 | | Field plot |
| 4 | | Radio set |
| 5 | | House in banco |
| 6 | | Bike |
| | | **Poverty line (1-6)** |
| 7 | Moderately well-off | banco house in sheet metal |
| 8 | | motorbike |
| 9 | | secondary education |
| 10 | | Goats/Sheep/Pigs |
| 11 | | solar panel at home |
| 12 | | Increase in field area |
| | | **Prosperity line (13-22)** |
| 13 | Nantis | Sheet metal house |
| 14 | | Electricity at home |
| 15 | | Solar panel |
| 16 | | Motorbike |
| 17 | | Shop |
| 18 | | Goats/Sheep |
| 19 | | Steers |

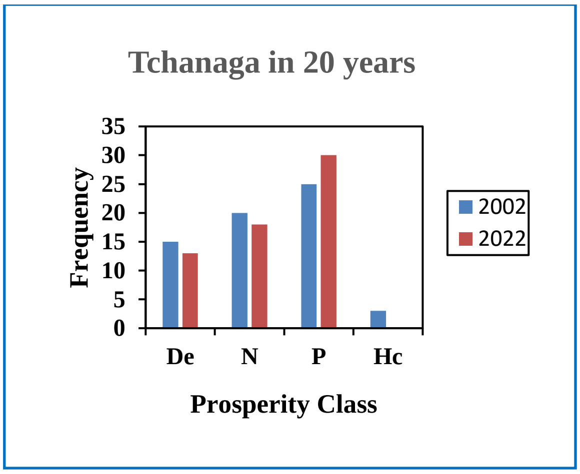
- **Evolution of prosperity classes by year, by locality**

Figure 8 shows the evolution of prosperity classes from the year of the major event to 2002, in the three localities studied. It can be seen that the local populations of Tchanaga, Sadori and Péssidè are distributed among the three prosperity classes (Deprived, Moderately Well Off, Well Off). As the gap between the year 2002 and 2022 was large in the three localities, individuals outside the class were identified. Because of their young age, these individuals were hardly working at all in 2002.

The main finding is that there has been an increase in the number of affluent people and a decrease in the number of middle-income and poor people. The major events have obviously had negative repercussions on the economies of the local populations at both individual and local levels. After these difficult years, the repercussions can be seen in the movement of farmers in the Oti wetlands from one class to another or simply from one level of the class to another.



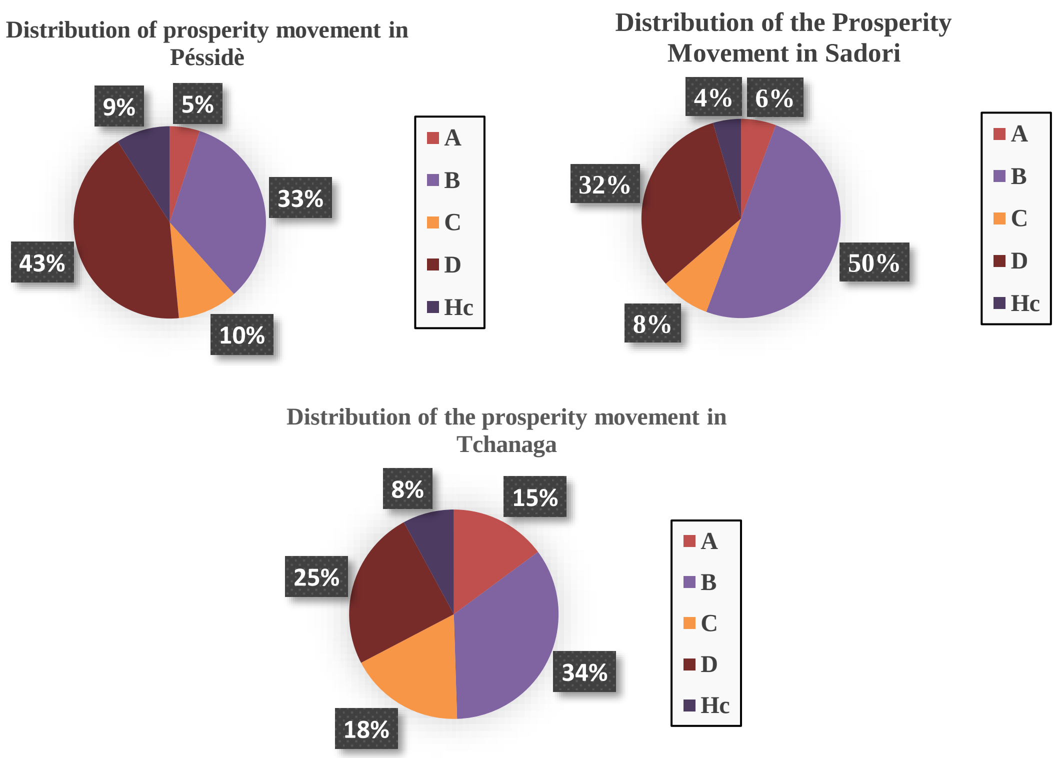



*Legend: P: Well off N: Moderately well off De: Deprived HC: Out of class*

*Fig.8: Evolution of prosperity classes in the 3 localities according to the year*

- **Breakdown of poverty movements by year, by locality**

The study of the various movements has made it possible to distinguish four categories of individuals between 2002 and 2022: those who were poor and remained poor (A); the poor who became moderately well-off or well-off (B); the well-off who became poor (C); and finally the non-poor who retained their non-poor status (D). Figure 9 shows the distribution of poverty movements in the three localities. It shows that, in all these localities, the highest proportions were found among individuals in category B, which means that the majority of moderately well-off farmers either remained as they were or moved into the well-off category. The affluent individuals either remained affluent or became affluent. Assessing the magnitudes of these movements enables us to determine whether they are positive or negative.

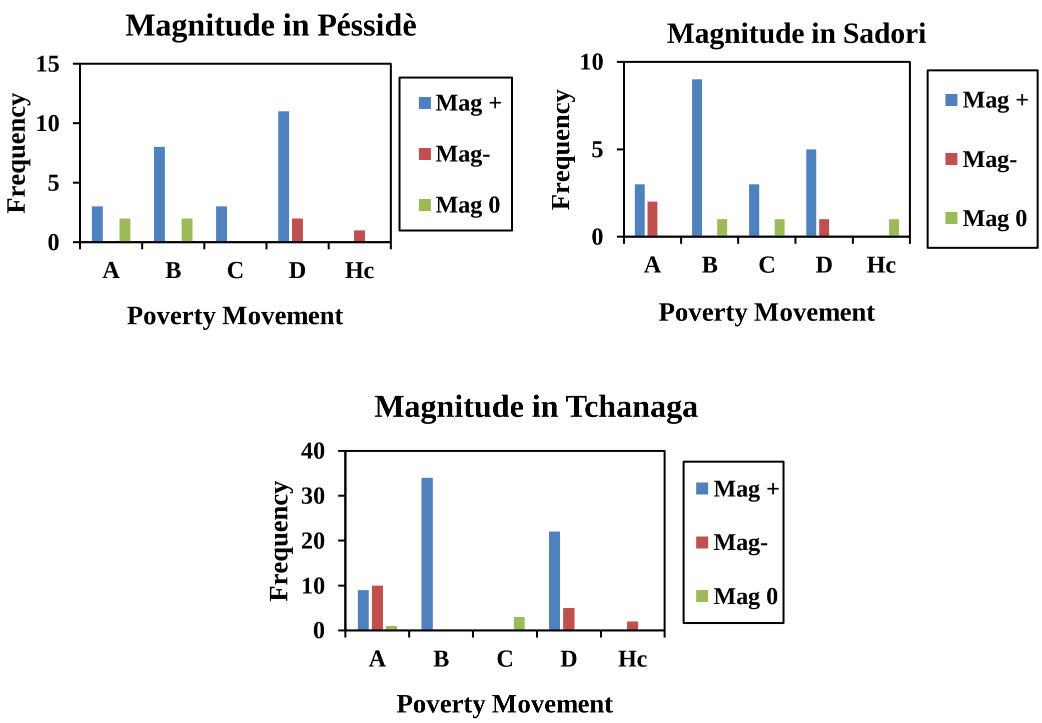


*Legend: A: still poor in 2022; B: poor in 2002 and not poor in 2022 ; C: not poor in 2002 and poor in 2022; D: not poor in 2002 and still not poor in 2022; HC: out of class.*

*Fig.9: Distribution of poverty movements by locality*

- **The magnitude of the poverty movement in the three localities**

Figure 10 shows the evolution of the magnitude of movements in the three locations studied. In category A, and only in Péssidè, there were no negative magnitudes, but rather positive and zero magnitudes. This means that without having left the prosperity class that characterised them at the outset, individuals have moved to a higher level or remained stable on the prosperity scale. The exception is Tchanaga, where the movements of individuals in category B are characterised by positive and zero magnitudes. It can also be seen that for individuals who were once rich but are now poor in Péssidè, the magnitudes are positive, while in Sadori and Tchanaga they are positive and zero. The diversity of magnitudes is found in category B insofar as poverty status has changed in Nantis.




*Legend:* A: always poor in 2022; B: poor in 2002 and not poor in 2022 ; C: not poor in 2002 and poor in 2022; D: not poor in 2002 and still not poor in 2022; HC: out of class: Mag + = Positive magnitude; Mag - = Negative magnitude Mag 0 = Zero magnitude

*Fig.10: Magnitude of poverty movement in the 3 localities*

## IV. DISCUSSION

- **Spatio-temporal dynamics of land-use units in wetlands**

The results of our study showed that the dynamics of land-use units in the wetlands of the Oti plain over the period 1987-2019 saw a decline in the natural units characteristic of wetlands, in particular water bodies (ponds and swamps), forest gallery, wooded and grassy savannahs, in favour of bare soil, crops and built-up areas.

In fact, the area of wooded savannah and grassy savannah has shrunk exponentially over the last thirty years, with rates of regression of -22.98% and -8.15% respectively. Crops and settlements have increased by 24.69% of the area they occupied in 1987. As a result, a large portion of the wetland that was covered by natural formations in 1987 is now covered either by man-made units (crops and settlements) or by bare soil in 2019. The forest gallery, which represented 1% of wetland vegetation cover in 1987 and protected the banks of watercourses, has regressed with an expansion rate of -0.15% and has been transformed into arable land. The ponds and marshes that make up the lungs of the wetlands have dried up due to the droughts experienced by the country in the 1980s or have gradually been transformed into cultivated areas, which justifies the reduction in their surface area from 18% in 1987 to 7.61% in 2019.

Overall, the surface area of man-made formations (crops and settlements) in the wetlands of the Oti plain increased over the period 1987-2019. The increase in the surface area of these units is caused by urbanisation coupled with galloping demographics and the ever-growing need for biological resources and arable land, most often to the detriment of savannah areas. This confirms the results of the work of IWEDIGA and al, (2012), DIMOBE and al, (2012), DIOP and al, (2018), BRUN and al, (2018) concerning the loss of dense plant formations in favour of agricultural areas. Indeed, the work of IWEDIGA and al, (2012) showed that off-season agricultural practices on the banks of watercourses in the Oti plain had a negative impact on riparian vegetation, particularly gallery forests. Similarly, DIMOBE and al (2012) showed that human activities (hunting, fishing, medicinal plant harvesting, wood cutting and collection, charcoal burning, straw harvesting in the savannah, etc.) had a negative impact on riparian vegetation, particularly gallery forests, bush fires and transhumance) carried out in the Oti-Mandouri reserve have resulted in the rarefaction of certain plant species, a reduction in forest cover, the loss of animal habitats and biodiversity, soil erosion, changes in water regimes and climate disruption (Photo 1). In addition, the results of BRUN and al (2018) on the dynamics of land use in the wetlands of the Commune of Allada in southern Benin have highlighted the negative impact of man on wetlands. They showed that the major trends reveal a decline in natural formations in favour of man-made formations. The total disappearance of the shrub savannah shows man's strong hold on his natural environment, which provides immeasurable wealth to satisfy his vital needs.

Agreeing with his predecessors, ADJAKPA (2020) confirmed that the main factors in the degradation of the natural resources of wetlands are human activities that devastate the environment, such as shifting cultivation, the exploitation of forest products and transhumant livestock rearing, which are practised to an alarming degree. Heavy migration towards the wetlands is leading to the systematic over-exploitation of all natural resources. To reverse this trend, strategies based on ecological restoration, which consists of assisting the self-regeneration of degraded or destroyed ecosystems, should be implemented. This involves attempting to re-establish pre-existing plant formations, rather than forcing nature by trying to impose other biological models. Among the best strategies for safeguarding and saving ecosystems are the restoration and rehabilitation of terrestrial and aquatic ecosystems, ecological improvements in the use of biological resources, and the establishment or improvement of human behaviour that incorporates knowledge of the importance of natural capital, as well as its conservation and management.

*Clearing and cutting wood* *Transhumant breeding*

*Using wetlands to grow rice*

*Photo 1: A few shots showing how wetland resources are exploited.*

*Source: LAMBONI, 2023.*

- **Climatic vulnerability of the wetlands of the Oti plain**

The IPCC's assessment of climate change in September 2013 confirms that since 1901, temperatures measured at the Earth's surface have risen overall on average. According to the same report, global warming in Africa is likely to be greater than at global level (IPCC, 2013).

The warming detected in the north of Togo in the study area by analysing changes in average temperatures over the period 1970-2021 is part of this global warming trend. This analysis shows that average temperatures have increased over the comparative periods 1970-1995 and 1996-2021. There has been an increase in average minimum and maximum temperatures. The last quarter of the century has been the warmest, with temperatures rising by around one degree Celsius. These results are comparable to those carried out by ADAMELI and DUBREUIL, (2015) on temperature trends in Togo between 1961 and 2010. The results show a temperature increase of between 0.3 and 1.6°C, which has been more pronounced in the lowlands than in the mountain ranges since the late 1970s.

In the case of precipitation, the results of our work revealed a decline in precipitation over the last five decades (1970-2019). The period 1970-1995 was marked by significant inter-annual fluctuations, with rainfall of around 1,400 mm, compared with the period 1996-2021, when rainfall was around 1,000 mm. This represents a significant drop compared with the 1970s. This situation has resulted in a southward shift in isohyets.

All the results point to a downward trend in rainfall and an upward trend in temperature, with significant inter-annual variability accompanied by breaks in rainfall.

These changes are having a disastrous impact on wetland environments and populations. Global warming is causing land to gradually dry out and deteriorate, increasing farmers' dependence on wetlands in search of fertile wetlands (ADJONOU, 2009; BADJANA, 2010; DJENONTIN, 2010). Falling rainfall is leading to a reduction in the area of wetlands. One of the consequences of the general deterioration in the climate is the proliferation of floating vegetation (water lettuce, water hyacinth, typha, etc.), due in particular to the reduction in the flow velocity of watercourses, the change in their temperature and the deterioration in water quality. They are suffocating several bodies of water in the region, including wetlands whose biological diversity is recognised as being of worldwide importance (NIASSE et al, 2004) (photo2).

*Photo 2: Pond invaded by water hyacinth near Gando*
*Source: LAMBONI, 2022.*

- **Assessment of the socio-economic impact of wetland degradation on local populations**

It is widely recognised that the survival of Africa's rural populations depends on agricultural produce, timber and non-timber products. Local populations, mainly rural and agro-pastoralists, are highly dependent on natural resources that are highly sensitive to climate, which explains their vulnerability, given their low capacity to adapt (IPCC, 2004). The various adaptation strategies developed by these populations to cope with the adverse effects of climate change are increasing the pressure on wetland ecosystems in the Oti basin. Wetlands, particularly the floodplains of the Oti, represent a rich ecosystem that provides people with a means of subsistence as they strive to achieve food security. They also provide drinking water and are a last refuge for biodiversity. Against a backdrop of climate change and demographic pressure, these areas are increasingly coveted and under threat. Our research reveals a correlation between the level of prosperity and the state of natural resources. In all three localities, the number of wealthy people has increased, indicating a decline in poverty compared to the reference year. This is largely due to the exploitation and marketing of agricultural, fishing, hunting and livestock products. Many farmers have made their fortunes marketing oilseed crops such as soya and sesame over the last ten years. Since 2021, soya exports have generated nearly CFAF 50 billion in Togo (INSEED, 2022). This agricultural revolution, encouraged by government efforts, has had a positive impact on the socio-economic situation of farmers. However, it is increasing pressure on natural resources.

It is also recognised that poverty in rural areas is an obstacle to the sustainable management of natural resources (BELEM et al, 2006). This is why the World Bank's environmental action plan focuses on the poorest sections of society. It believes that reducing poverty will make it possible to improve the quality of the environment and reverse the spiral of degradation (WORLD BANK, 1997). Thus, the fight to maintain and preserve wetlands will involve reducing people's dependence on natural resources. Investment in reforestation and the creation of agroforestry parks will also create a favourable climate for maintaining diversity in the biosphere reserves.

## V. CONCLUSION

This study has enabled us to show that the areas of natural land use units on the Oti plain have been declining over the last thirty years. The main trends show a decline in natural formations in favour of man-made formations. Over the same period, the climate of the Oti plain has become highly variable, alternating between dry and wet periods, with a general trend towards lower rainfall and higher temperatures. The effects of this climate change, coupled with human-induced degradation factors, are having a negative impact on the socio-economic situation of the local population. The consequences of these human activities are leading to the degradation of natural resources. Work is therefore urgently needed to set up local structures with internal rules for the management, preservation and protection of the highly exploited natural resources of wetlands in order to preserve their sustainability.

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