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Effects of Pluviometric Variability on Rice (Oriza Sativa) Production in the Commune of Materi in Northeast Benin

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Abstract

This research analyzes the effects of rainfall variability on rice production in a context of predominantly rainfed agriculture in northwest Benin, specifically in Matéri. A methodology based on documentary research and diagnostic surveys was used to collect information on the effects of rainfall variability. It enabled the collection of information on rice yields, rainfall data (1990-2020) and temperatures (1990-2020). The determination of extreme rainfall years and the frequency and magnitude of extreme rainfall years, and the analysis of the effects of rainfall variation. The analysis of the results was done using the EPIR (State/Pressure/Impacts/Response) model. The analysis of the results indicates an overall decreasing trend in precipitation and an increase in temperature. Similarly, there was a slight decrease in rainfall in 1998 (yield: 1450 t vs. 1508.6 mm) despite a high rainfall. These results were confirmed by the perceptions of producers, who attested to them through the modification of the agricultural calendar (80%) due to the increase in agricultural land (46.26%), and vegetation fires (19.52%) attributable to, among other things, clearing and deforestation (11.34%). To cope with this situation, which threatens the livelihoods of households, producers have developed coping strategies such as extending the area (50%), adopting new crop varieties, changing crops and fighting against wildfires, etc.

Keywords : Materi commune ; lowlands ; rainfall variability ; adaptation measures.

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1. Introduction

Globally, agriculture is central to the 2050 sustainable development agenda, which aims to end poverty and promote human prosperity and well-being while protecting the environment (OCBE/FAO, 2016, p.23). It represents the most important sector in developing countries where it occupies nearly 48.2% of the working population while this rate is only 4.2% in developed countries [13]. The UNDP indicates that in order to meet the development challenges in West Africa, fight poverty and reduce unemployment among young people and women in Benin, it is important to increase the productivity and profitability of the agricultural sector [11]. The seasonality of the climate is determined by rainfall [20]. Thus, the main climatic factors that influence rice productivity are essentially temperature, rainfall regime, carbon fertilization, and surface water runoff [15]. Climate variability is felt in developing countries such as Benin and the effects of global warming through excess rainfall temperature, hot flashes, delayed rains, pockets of drought and causing flooding, soil degradation, desertification and disasters far exceed the resources available to cope with them [22. The cultivation of rice is part of the activities that aim to ensure the desertification of food habits in order to meet an increasingly growing demand in agricultural position. This rice-growing practice is often practiced during the rainy season in the lowlands and floodplains

In its desire to satisfy internal needs and generate surpluses for trade, the Beninese government plans to produce at least 1,000,000 tons of white rice per year by 2050 [12]. To this end, Benin intends to develop its natural resource potential for this production. Thus, more than 322,000 ha of cultivable rice land, including 205,000 ha of lowlands and 117,000 ha of floodplains [22], are still underdeveloped (less than 8% of this potential is currently exploited). Approximately 4,928 developable lowlands covering an area of 53 km^2, or 3.5% of its total area, have been detected [17]. But with the increase in rainfall variation, the situation is becoming more critical for all crops in general and rice production in particular; despite the fact that the Commune of Materi is provided with wetlands occupying 25% of its area. It is imperative to better understand the efforts made by farmers in the face of the adverse effects of rainfall variability, hence the need to assess the effects of rainfall variability on rice production in Materi. What are the impacts of rainfall variability on rice production ?

Located between 10° 38' and 11° 4' North latitude and 0° 48' and 1°10' East longitude and having a surface area of 4800 km2, the Municipality of Matéri is located in the North-West of the Republic of Benin and is one of the nine Communes of the Department of Atacora. It has 6 districts and 55 villages. Figure 1 shows the geographical location of the Commune of Matéri.

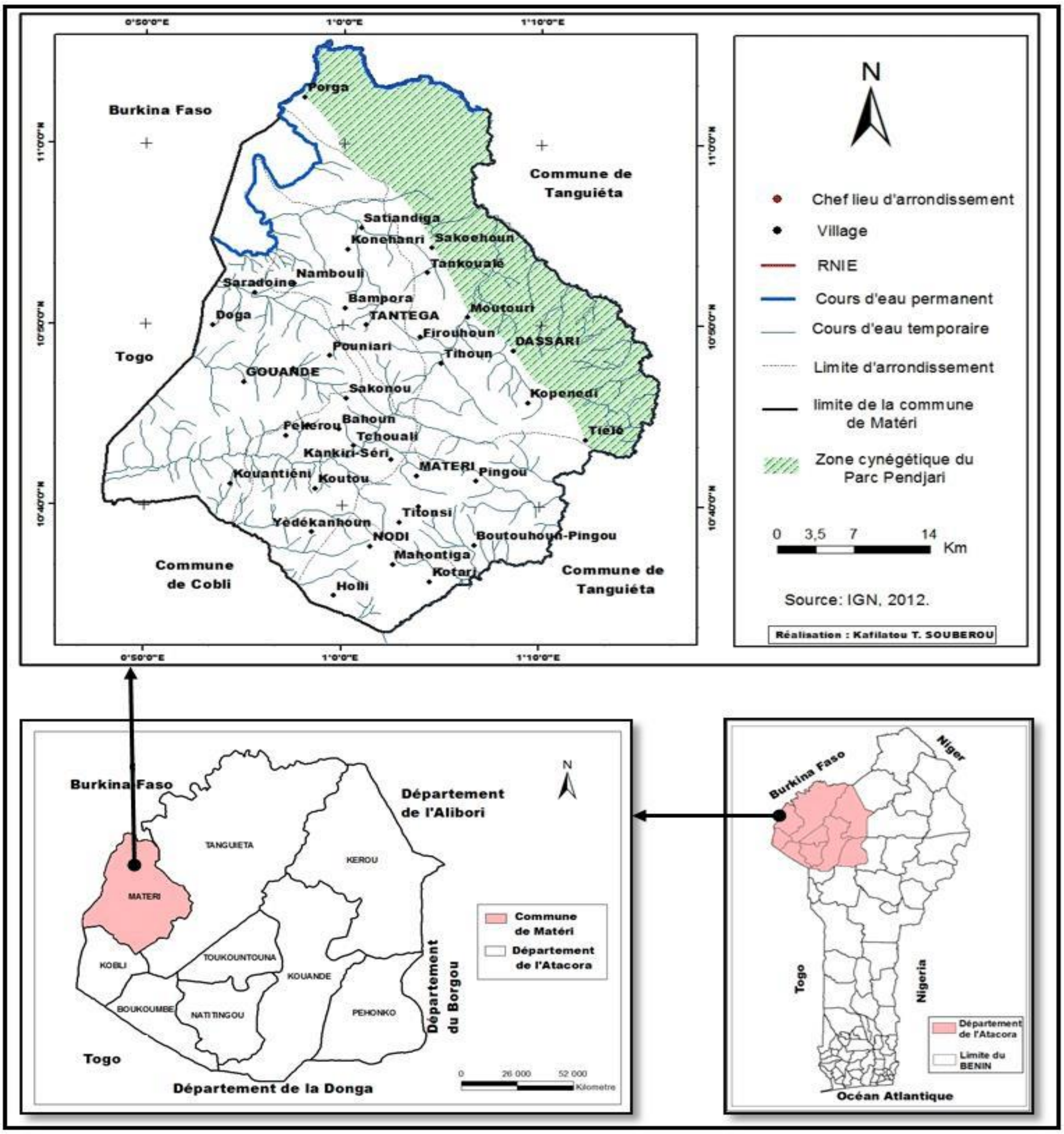

Figure 1: Geographical location of the Commune of Materi

Figure 1 presents the main factors of the Commune of Materi, highlighting its limits and contexts.

2. Data and methods

The materials and methods are focused on three main points: tools and materials in the first place, followed by data collection; data processing; and analysis and interpretation of results in the second place.

2.1. Data

The data used for this research are essentially climatological statistics (rainfall and temperature extracted from the Météo-Benin database) and come from the Natitingou synoptic station and the Taguiéta rainfall station over a period of 1990 to 2020 and planimetric data (pedological, geomorphological, hydrographic and geographic coordinates) using GPS. In addition to these data, demographic data from the results of the 1979, 1992, 2002 and 2013 censuses of the INStaD; data on crop production extracted from the MAEP compendiums; qualitative data on the dynamic vision of farmers; and the agricultural calendar collected during field surveys. In addition, direct observation has allowed us to understand the mode of cultivation, cultivation practices and endogenous strategies for adapting agriculture to climate change. The information collected was then used to prepare semi-structured interview guides, questionnaires and the observation grid for primary data collection.

2.2. Methods

It is done through documentary research and field surveys.

2.2.1. Sampling and collection techniques

The selection of the farmers surveyed meets the following criteria: they must be at least 30 years old and have been farming for at least the last 10 years; they must have lived in the locality for at least the last 15 years. The sample includes all six districts in the study area. In each of the districts of Gouandé, Materi, Dassari, Nodi, Tantéga, and Tchanhoun-Cossi. Individuals were interviewed in each district. The targets are designated according to their production capacity. Thus, Gouandé, Materi and Dassari have a high production capacity, while Tantéga and Tchanhoun-Cossi have low agricultural production.

In fine, 21 villages were targeted, 160 producers, six (06) village groups were surveyed in the Communes and five (5) ATDA technicians and NGO managers were interviewed.

The data were collected in two complementary phases. The first is the document review phase. It allowed for the assembly, exploitation, analysis and synthesis of the available documentation on the rice sector. Several techniques were used during the field investigations. The Itinerary method was used to identify resource persons who could provide data to achieve the objectives. In the second phase, a questionnaire was administered to each rice farmer. Focus group interviews were conducted in some villages. Individual interviews with ATDA technicians and leaders of farmers' organizations, etc., helped to understand changes in farming practices in response to new climatic requirements. In addition, the data collected during the focus groups helped to compare and complete the information collected.

The various data collected were processed and analyzed using essentially statistical methods.

2.2.2. Data processing and analysis of results

Data processing began with the tabulation and coding of the survey forms, observation guides, questionnaires and interview guides on the computer.

The analysis of rainfall variability allowed us to see their effects on rice production. To determine rainfall variability over the 1990-2020 series, the arithmetic mean was calculated. This arithmetic mean is taken as the normal rainfall situation for the series.

As for the adaptation and mitigation strategies for the effects of rainfall variations, the calculation of the frequency of quotation of the mentioned adaptation strategies allowed to highlight the main measures taken by the populations in their concern to mitigate the negative effects they felt or to protect themselves against these effects. Also, the EPIR model was used to indicate the state in which the study area is, to determine the pressure factors that induced this state, the imbalance, the vulnerability and the fragility that followed.

3. Results and discussion

3.1. Agricultural potential of the Commune of Matéri

The agricultural potential of Matéri Commune is based on the existence of lowlands, fields and fallow land available in the terroir. The lowlands are estimated at more than 9,200 ha of which more than 2,201 ha (≥ 24%) are exploited for the cultivation of rice, yams, cassava and market garden produce. There is a real agricultural workforce in Matéri (94% of agricultural households). The proximity of Togo and Burkina-Faso favors the entry of cheap agricultural workers into the Commune, who assist in the exploitation of the land. The Commune is a highly irrigated area with a rainfall of 900 to 1200 mm. There has also been a significant increase in the use of animal traction in the Commune, with bovine traction used for ploughing and asinine traction for transport. In addition, the State's policy in the sector aims at agricultural mechanization through the provision of tractors and other accessories to the Commune. Approximately 75% of plowing is done with tractors and the remaining 25% with the daba.

The Commune of Materi has experienced rapid population growth over time. Indeed, from 2002 to 2013 its population increased from 83721 to 113958 inhabitants including 70,089 men and 74,725 women (RGPH4). With an annual growth rate of 3.73%. The application of this rate has made it possible, based on information collected at the INSTAD, to project the population of the Municipality of Materi until 2021 (Figure 4).

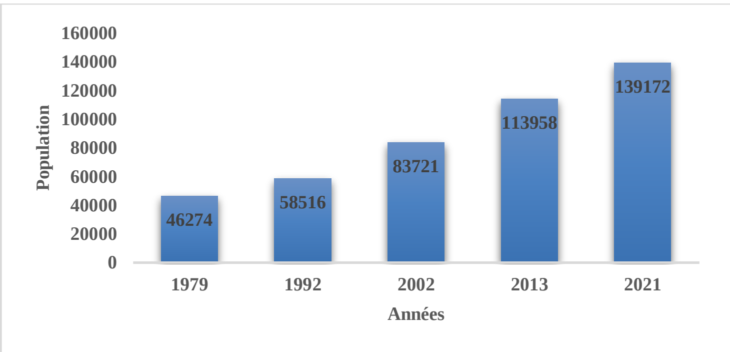

Figure 2: Projected population growth in the Commune of Materi

Source: INSTaD, February 2013

Figure 2 shows the evolution of the population of Materi from 1979 to 2013, with an estimate until 2021. The Commune thus has a significant number of inhabitants. This population is characterized in large part by an important margin of young people, mostly farmers. This rejuvenation of the population is a factor of dynamism, especially for agriculture. With the rainfall variations, this Commune will live in an overpopulated environment and could be confronted with food security.

3.2. Climatic variability of the Municipality of Matéri

The study of climate variability takes into account the evolution of rainfall and temperature in the study area.

3.2.1. Evolution of rainfall in the Commune of Matéri over the period 1990-2020

Rainfall in the study area is marked by a unimodal regime. The variability of rainfall is manifested by a significant change in rainfall patterns.

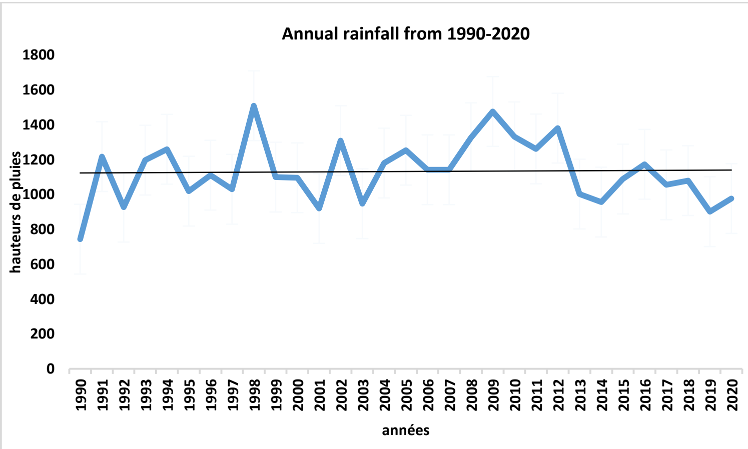

Figure 3: Inter-annual evolution of rainfall over the period 1990-2020

The analysis of Figure 3 shows that the Commune of Materi has experienced since the 1990s a rainfall variability marked by alternating years of surplus and deficit.

Table 1: List of surplus, average and deficit years over the period 1990-2021

Station	Years Deficit	Years Average	Years Surplus
Materi	1990, 1992, 1993, 2001, 2003, 2014, 2019, 2020	1994,1995,1996,1997,1999,2000,2004,2005,2006,2007,2011,2013,2015,2016,2017,2018	1998, 2002, 2008, 2009, 2010, 2012

Analysis of Table I shows that overall the decades 1990, 2000 and 2010 are wet. The years 1988, 2002, 2008, 2009, 2010 and 2012 are exceptionally wet. In contrast, the years 1990, 1992, 1993,2001, 2003, 2014, 2019 and 2020 are exceptionally dry. This rainfall variation is coupled with thermal warming (Figure 7), which imposes agronomic constraints.

3.2.2. Thermal evolution over the period 1990-2020

The evolution of maximum and minimum temperatures is presented in figure 8 below. Temperatures are high throughout the year with minimums between 23 and 24 °C and maximums between 35 and 36 °C. Figure 8 shows the evolution of maximum, minimum and average temperatures.

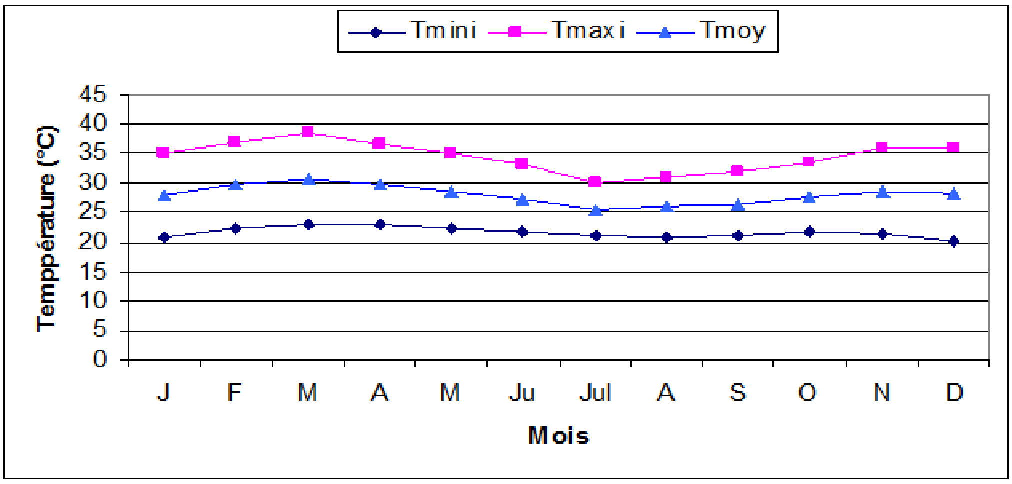

Figure 4: Inter-annual evolution of the temperature in the Commune of Materi

Source: Météo-Benin, May 2021 (Natitingou synoptic station)

The analysis of the data in Figure 8 shows that February, March and April are the hottest months, with an average of 38°C. The least warm months are December, January and August with an average of 23°C. The trends in maximum and minimum temperatures show that thermal warming is affecting the municipality of Matéri. The observed increase is 1.5°C. Similarly, minimum temperatures have also increased throughout the Commune. They went from 21.1 to 22.9°C with an average of 22.1°C and from 21.8 to 24.1°C. In addition, 57% of those surveyed said that it is currently warmer than before.

3.3. Evolution of rice yields in relation to rainfall

The evolution of crop yields in the Commune between 1995-2020 in relation to rainfall at the Natitingou station, which is the only synoptic station in the entire study area, is shown in.

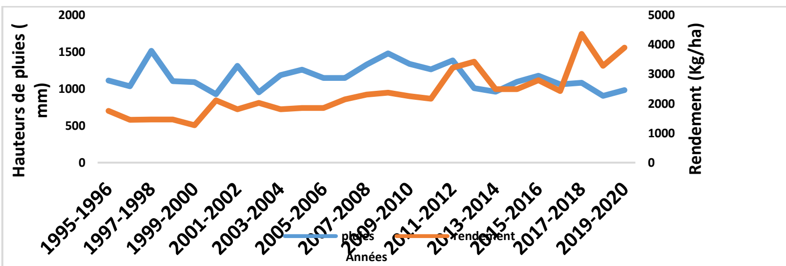

Figure 5: Evolution of rice yields in relation to rainfall

From 1995 to 2020, the average annual yield exceeded the 2T/ha mark for the first time, reaching 3.405T/ha in 2012-2013 as a result of the efforts made by various structures, in particular the Programme d'Urgence d'Appui à la Sécurité Alimentaire (PUASA), which provided large quantities of fertilizer and free certified seed, before reaching its maximum (3.924 T/ha) during the 2017-2018 rice growing season.

There was a slight decrease below the rainfall in 1998 (yield: 1450T vs. 1508.6 mm) despite high rainfall. This can be explained by the fact that rainfall was unevenly distributed or that it is not the only element that determines rice yields, but that there are other factors that disrupt their evolution.

In sum, the decline in crop yields in the study area depends on rainfall, among other things. This decline in agricultural yields constitutes an agri-food risk in the Commune and puts farmers in critical situations. Rainfall fluctuations have socio-economic repercussions. In sum, the unfavorable climatic dynamics have led the populations to develop several adaptation strategies to reduce their vulnerability.

3.4. Farmers' perceptions of rainfall variability

According to the surveys, there are different perceptions of rainfall variability among the population. For some, the climate has changed, with a normal disruption of agricultural activities and a chronic decline in yields for 20%. For others, it is just a late start and/or poor distribution of rainfall, according to 80% of those surveyed, which translates into a change in the course of the agricultural season, modifying the agricultural calendar of the Commune of Materi. Figure 6 presents a summary of farmers' perceptions of rainfall variability.

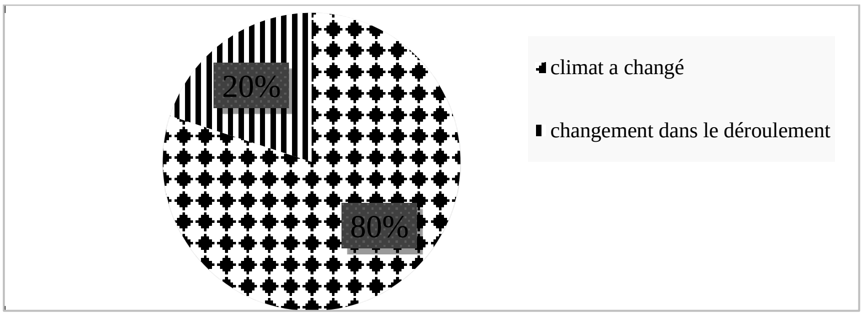

Figure 6: Summary of farmers' perceptions of rainfall variability

Source: Field surveys, August 2021

Analysis of Figure 6 shows that 80% of respondents perceive changes in rainfall as a late start and/or poor distribution of rainfall, which results in a change in the agricultural season that modifies the agricultural calendar of the Commune of Matéri, compared to 20% of farmers in the Commune who believe that the climate has changed, which results in a normal disruption of agricultural activities and a chronic decline in yields.

Figure 7 highlights the causes of rainfall variability as perceived by local populations.

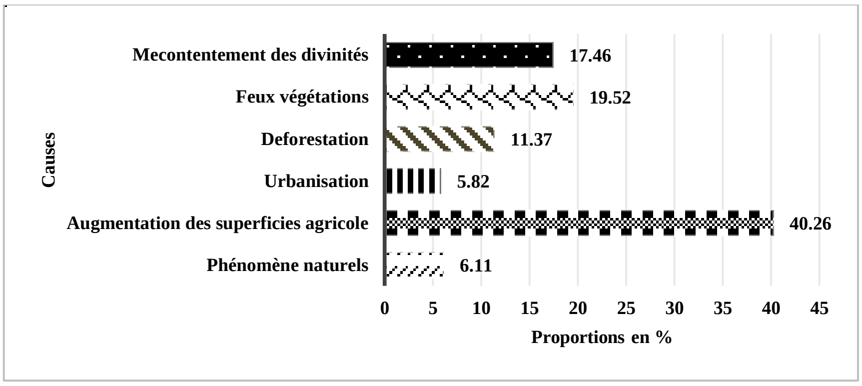

Figure 7 : Causes of rainfall variability

Source: Field surveys, June 2021

From the analysis of Figure 7, it appears that the increase in agricultural land is the most cited by producers (46.26%). After the increase in agricultural land, the most cited causes are vegetation fires (19.52%), which are attributable to clearing and hunting, among other things, and contribute to deforestation (11.34%).

3.5. Producers' Perceptions of the Occurrence of Rainfall Variability

It is important to note that young people perceive rainfall variability less than adults and older people, given that the average age of the young people in the sample considered here is 32 years. However, a period of 30 years is required for an appreciation of the manifestations of rainfall variability, which explains why this perception is more notable among adults and the elderly. With regard to temperature and sunshine, producers estimate an increase in temperature (90% of respondents), accompanied by a higher level of insolation (92.43%). This level of insolation devastates the crops and causes significant economic losses.

3.6. Adaptation strategies and strengthening measures

❖**Increasing the number of hectares planted**

Faced with declining yields, 32.27% of the producers surveyed have increased the number of hectares planted, as a means of maintaining an acceptable level of annual rice production in view of the chronic decline in yields.

Photo 4: Lowlands at Atenega

Shot: G.C. Wokou, May, 2021

❖***Professional conversion***

After agricultural activities, in the dry season some people turn to trade, to sheep breeding, which is sufficiently lucrative to supplement their agricultural income and to meet their daily needs such as health and schooling for their children. Some become poultry and sheep dealers, and the young people who make up the labor force are more involved in motorcycle cabs. Figure 15 summarizes the results obtained from the study of rainfall changes and its effect on agricultural production.

❖**Adoption of short-cycle varieties**

The drought has led to mitigation measures being taken by producers to cope with the food shortage. This change in rainfall has gradually led to the replacement of certain crop varieties.

Table 2: Rice varieties encountered

Crop	Old varieties	New varieties adopted
Rice	Gambiaka, Nerica, Nerical, ITTA 222, Wabo	Ir841, beris21

Source: Field surveys, March 2021

From the analysis of Table II, it appears that the variety IR841, with a 120-day cycle and greater resistance to drought, has gained ground over Gambiaka, with a short cycle of 90 days and 110 days and less resistance to drought, as well as the variety Nerical, which is gradually disappearing in favor of Beris 21. Also, the variety being tested is BRIZ-1P, which is adapted to short-cycle drought-resistant conditions (less than 110 days and a potential yield of 4 tons).

❖**Training of farmers**

Here, farmers need to be trained in the techniques for exploiting the different ecosystems. ATDA agents should emphasize the production techniques of new varieties. It should be noted that efforts are being made in this area through the presence of supervisors in the field. However, these efforts remain limited due to the technical support needs expressed by the farmers. For this, it is desirable to form a group in each sector composed of agricultural researchers and farmers. This will allow farmers and researchers to develop techniques together.

For this supervision of farmers, the government must pay the supervisors' salaries and travel expenses (at least one motorcycle).

❖**Strengthening research**

It is a question of deepening research in order to make available to farmers varieties that are more resistant to water deficit, with shorter and shorter cycles, low water requirements and high yields. To do this, the structures in charge of this research in Benin such as INRAB, MAEP, FSA and Rural Geography (GR) etc. should take into account the current climate changes and the changes announced to propose and make available to farmers improved varieties capable of adapting to the current soil and climatic conditions in order to reduce the problems of yield decline.

❖Financing agricultural production

The efforts made in this area in Benin have not always been brilliant. They have contributed more to the impoverishment of farmers. Lanokou M. (2009), p.59, rightly states that financing is not accompanied by a follow-up and the working tools are not made taking into account the pedoclimatic realities of our country, but also and above all because the beneficiaries are not trained beforehand for their possible use. It is necessary that the State and the local authorities come to a common agreement to accompany the farmers.

❖Improved seeding techniques

Staggered planting consists of planting the same crop on two plots at different dates. The practice of staggered sowing allows producers to ensure that one of the crops corresponds to the rainfall pattern in the event of a break in rainfall. The primary objective is to compensate for rainfall patterns according to the phrenological requirements of the crop and also to obtain a good yield.

As for repeated sowing, this consists of sowing the same crop several times on the plots during the agricultural season, and allows for "reseeding", i.e. replacing rice plants that have withered as a result of water shortages following a rainfall break. This technique protects the new plants from drying out and allows producers to reduce seed loss due to excess heat, and promotes good crop growth and development. It allows for a good yield after harvest.

4. Discussion

The climatic context in Benin has been marked for several decades by seasonal and thermal rainfall variability that has a significant impact on the biophysical environment. This is corroborated by studies carried out at the national level by several actors in the scientific world.

An analysis of these different climatic parameters shows a statistically significant variation, characterized by a decrease in rainfall around an average that reveals, however, a general downward trend between the minimum values 750 mm and maximum 1500 mm with a period, below the average, between the years 1990, 1992, 1993, 2001, 2003, 2014, 2019 and 2020). This denotes a remarkable variability in the rainfall regime of the Commune and a rise in temperatures of about 38°C. The least warm months are December, January, July and August with an average of 23°C. These results are consistent with those of [3] who estimate that overall, the trend is towards an increase in average annual temperatures, and a decrease in average annual rainfall for the three climatic zones of Benin. From these results, we deduce that the Commune of Materi experiences rainfall variability and therefore, several factors explain the rainfall fluctuations in the Commune of Materi. The results of [9] corroborate the rainfall variability and rice production in the Commune of Glazoué.

Also, these climatic disruptions have resulted in the disruption of the agricultural calendar, and the reduction of agricultural yields (80%). This reduces the harvest per hectare. Because rainfall fluctuations affect rice yields in the Commune.

To reduce the effects of climatic parameters on crops, people are developing adaptation strategies such as extending the area under cultivation (32.27%), adopting new crop varieties (19.54%), changing crops and fighting vegetation fires, etc. The analysis of these results is consistent with the work of E. Ogouwalé (2006, p.253), etc., who explain that in the face of the impact of climate change on crops, agricultural producers develop adaptation strategies, which are among others those described in this study. For these authors, adaptation and mitigation to climate change are consequently inescapable. Hence, the strategies adopted in the face of climate variability vary according to the varieties practiced in the Commune.

5. Conclusion

The Commune of Matéri has a natural and human potential for rice production. This production remains essentially rainfed, so that the producers' calendar is based on the normal distribution of rainfall during the year. The succession of surplus and deficit years in annual rainfall has induced a local representation of climatic variations and the adoption of new modes of exercising the activity of rice production among the populations of the Commune of Matéri. The production and profitability of this crop remain dependent on rainfall. In this context of rain-fed agriculture, changes in rainfall patterns lead to disruptions that have profound repercussions on the lives of farmers. Faced with this constraint, farmers have developed adaptive measures based on their perceptions and empirical knowledge. However, relevant complementary support measures need to be implemented to reduce the vulnerability of rice production to rainfall shocks. To this end, all stakeholders (producers, the state, technical and financial partners) should combine their efforts in a synergistic and inclusive approach.

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