

Land Tenure and Environmental Dynamics- Adaptive Strategies to Ensure Food Security in the Municipalities of Djakotomey and Aplahoue in Southwest Benin

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How to cite this paper: Dandjekpo, A., Kadjegbin, T. R. G., & Djessonou, S. F.-N. C. (2026). Land Tenure and Environmental Dynamics-Adaptive Strategies to Ensure Food Security in the Municipalities of Djakotomey and Aplahoue in Southwest Benin. *Journal of Geoscience and Environment Protection*, 14, 245-264.
<https://doi.org/10.4236/gep.2026.141014>

Received: October 20, 2025

Accepted: January 20, 2026

Published: January 23, 2026

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Abstract

Land is a vital source of wealth and plays a significant role in food security for the populations of the municipalities of Djakotomey and Aplahoue. This research focuses on land tenure and environmental dynamics-adaptive strategies to ensure food security in these municipalities. Climatological, agricultural, and economic data have been analyzed with appropriate statistical tools (index and ratio). SPSS 17.0 and ArcView 3.2 software have been used to process data. Findings reveal that land tenure insecurity is relatively high in the municipalities of Aplahoue and Djakotomey. Also, rainfall indices range from -2.05 to 3.72 over the study period (1961-2023). Urban expansion often encroaches on agricultural land. Moreover, plot splitting rates rise from 32% in 1990 to 81% in 2024, with a growth rate of 153.12%. Areas are highly prone to flooding (57%). Hence, the research area is subject to flooding and water erosion. Local communities develop convenient strategies to address this situation. These include the use of crop residues, composting, crop rotation, improved fallow, intercropping, crop rotation, altering the agricultural calendar, repeated and staggered sowing, increasing the area under production, developing low-lying areas, rescheduling the agricultural calendar, using improved seeds, irrigation techniques, switching to other economic activities, and organizing prayer sessions.

Keywords

Municipalities of Djakotomey and Aplahoue, Adaptive Strategies, Land and Environmental Dynamics

1. Introduction

Increasing pressure is being put on land tenure systems due to growing populations and demand for food security, while environmental degradation and climate change are reducing the availability of land, fisheries, and forests. Poorly designed and insecure land rights increase vulnerability, hunger, and poverty, and can lead to environmental degradation and conflict when rival users compete for control of these resources (CSA, 2015). Soil depletion is a global environmental issue. It directly affects the livelihoods of millions of people, especially the poorest and most vulnerable in the world's drylands, where more than 500 million hectares of land are eroded. It negatively impacts the ability to increase food production required to meet the food needs of a fast-growing population (GEF, 2014). Land deterioration affects 1.5 billion people and 74% of the world's poor populations. It hinders agricultural production and increases poverty and vulnerability. It affects 33% of the world's land area, impacting more than 2.6 billion people in over 100 countries (ELD, 2015). Agricultural sectors also bear a huge burden in feeding a growing global population during the height of climate change. More frequent and extreme weather events and increased climate variability threaten agriculture, livelihoods, and infrastructure (FAO, 2016). Farmers, herders, fishermen, and foresters within communities depend on activities that are closely and inextricably bound to the climate. They are most affected by climate change, yet they are less equipped to cope with it. Climate change in Niger has led to a steady rise in temperatures since the 1980s and 1990s (OCDE, 2022). The hottest years, clustered around 2000 and 2010, as is the case worldwide, have witnessed an average increase of around $+1.13^{\circ}\text{C}$, with record increases reaching 1.7°C compared to 1961-1990 normal temperatures. Also, between the current period and the normal period from 1961 to 1990, the number of nights, days, and heat waves have nearly doubled (AMCC, 2015). The recent period is also characterized by increased variability in rainfall and its components, such as agricultural season start dates and length, which seems to be boosted by climate change. In addition, a downward trend in the number of rainfall events has been recorded, although combined with intensified rainfall and a resurgence of heavy rainfall in some areas, leading to flooding (Orou Seko, 2019). Very small farms are shrinking as a result of splitting following inheritance. Fallow land becomes scarcer in some southern areas, such as the Adja plateau, where it has almost disappeared. A strong population growth has been observed in most regions of Benin over the last two decades, especially in Couffo Department (Dandjekpo, 2018). Agriculture's best response to climate change is to adopt convenient endogenous strategies such as using short-cycle varieties, adopting new farming techniques, and diversifying crops in the Sahelian and Sudano-Sahelian zones of Burkina Faso (Bougma et al., 2018). Farmers' adaptation solutions to weather threats fall into three broad categories: genetic, environmental, and other practices (FAO, 2024). The objective of the research is to analyze the endogenous adaptation strategies of subsistence farmers in the communes of Djakotomey and Aplahoue in the face of the effects of land and envi-

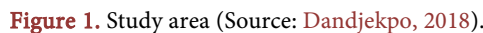
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Journal of Geoscience and Environment Protection

DOI: 10.4236/gep.2026.141014

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DOI: 10.4236/gep.2026.141014



The municipality of Djakotomey is divided into ten (10) districts (Djakotomey I and II, Bétoumey, Kpoba, Kinkinhoué, Adjintimey, Sokouhoué, Houégamey, Kokohoué, Gohomey) and seventy-two (72) villages and city districts. It covers an area of 235 km². In contrast, the municipality of Aplahoué has an area of 915 km² and is subdivided into seven (07) districts: Aplahoué, Atomey, Azovè, Dékpo, Godohou, Kissamey, and Lonkly. These districts are further divided into ninety-two (92) villages and city districts.

2.2. Data Used and Collection Techniques

Several data have been used to analyze endogenous or non-endogenous adaptation strategies developed by local farmers in the municipalities of Djakotomey and Aplahoué in response to the effects of land tenure and environmental dynamics. These include people's views on endogenous adaptation strategies, providing insight into the effectiveness of the convenient methods adopted by stakeholders in response to land and environmental dynamics, and people's views on physical factors (climate, terrain, soil, and river systems), helping to analyze stakeholders' adaptation strategies. Participant feedback, individual interviews, direct interviews, focus groups, and Rapid Rural Appraisal are the main techniques used during field surveys. A sample had to be determined in order to conduct socio-anthropological surveys. Given the importance of land and environmental dynamics in most of the villages to be visited, all districts in both municipalities have been taken into account. In short, 440 people have been individually interviewed during field investigations.

2.3. Urbanization Rate

This refers to the urban population (city dwellers) as part of the municipal population. Due to suburbanization, this rate is getting harder to figure out. It is calculated based on all residents in districts that are classified as urban. The statistical protocol is: $TUT = PAU/PTC \times 100$ (INSAE, 2013). With TUT = Theoretical urbanization rate; PAU = Urban District Population; PTC = Overall population in the research area.

2.4. Land Security Analysis

Land security has been classified into three (03) categories, namely high land security areas, medium land security areas, and low land security areas (Table 1).

Areas with high land security are characterized by completed land subdivision, allocated land reserves, continuous land occupation, available sanitation, available occupancy permits, available land titles for developed or inhabited plots, urban densification, and the presence of infrastructure. The medium land security zone is characterized by low-density occupation in neighborhoods undergoing subdivision, the presence of plots with residential permits in peripheral expansion or urban core densification zones, basic infrastructure, and land reserves for future infrastructure development. Low-security zones are mainly characterized by pe-

ripheral expansion with discontinuous occupation, where subdivision or development work has been suspended. In medium- and high-security areas, the boundaries of land conflict zones (identified by questionnaire) are defined. These boundaries are obtained by GPS tracking in the field and projected onto maps using Map Source software. Data conversion in QGIS is then necessary to create the “boundary” layer in polygon form.

Table 1. Defining land security areas.

Land security criteria	Secure tenure level
Completed subdivision	High land security zones
Allocated land reserve	
Continuous occupation	
Available sewage system	
Available occupancy permit	
Available land title	
Urban core densification	
Major infrastructure	
Available for occupancy	
Subdivision in progress	
Urban expansion	Medium security zones
Low density occupancy	
Basic infrastructure	
Suspended housing development	
Peripheral expansion	Low land tenure areas
Discontinuous occupation	
Urban constraints	

Source: documentary research, August 2024.

2.5. Plot Splitting Rate

Land splitting is defined as the degree to which agricultural land is divided into small plots (Djessonou, 2023). The dispersion coefficient of the plots (average distance between plots on the same farm) can also be calculated.

2.6. Agro-Demographic Index (ID) and Spatial Accessibility

This is assessed by the presence of infrastructure and maintenance activities that respect agricultural activity. Thanks to the agro-demographic index, it is possible to analyze pressure on land through changes in crop cultivation per capita in relation to demographic trends in the municipalities of Djakotomey and Aplahoue. This indicator for assessing anthropogenic pressure on natural resources is determined based on population growth determined from the years 1979, 1992, 2002, 2013, and 2050, using the formula employed by (Wokou, 2014): $ID = S/P$ where: S is the total cultivable area of the municipality and P is the population from 1979 to 2050. If:

ID < 0.5 then the area is under severe pressure (highly threatened);

0.5 < ID < 1 then space is moderately threatened;

ID > 7 then the space is under low pressure (not threatened).

Abnormal years are identified based on the Standardized Precipitation Index used for this research (Djessonou, 2023). Standardized abnormal indices are computed through:

$$IAS = \frac{X_i - \bar{X}}{\sigma(X)}$$

where X_i represents the average annual rainfall for year i ; $\bar{X}$ and $\sigma(X)$ represent respectively the mean and standard deviation of the series considered. Under this index, a year is considered normal if its index is between -0.1 and $+0.1$. It is deemed wet if its index is above 0.1 and dry if it is less than -0.1 . The computed trends helped confirm the sequential trends (upward or downward) highlighted by moving averages and breaks, characterizing wet or dry years. In addition, when the index is consecutively negative and reaches an intensity of -1 or less, a drought occurs, ending when the index becomes positive. Droughts are classified according to the index values (Table 2).

Table 2. Index value determination.

Index value	Drought spell
$-0.99 \text{ à } 0.99$	Almost normal
$-1.00 \text{ à } -1.49$	Moderately dry
$-1.50 \text{ à } -1.99$	Severely dry
-2.00 et moins	Extremely dry
$2 < IAS$	Extreme moisture
$1.5 < IAS < 1.99$	Severe moisture
$1 < IAS < 1.49$	Moderate moisture

Source: Djessonou, 2023.

The computed trends helped confirm the sequential drought trends highlighted by the index values. Sequential drought trends were identified based on variables (Moderately Dry, Severely Dry, Extreme Moisture, Severe Moisture, and Moderate Moisture). Trends are highlighted using a linear regression line: $y = ax + b$; where y is the value of any variable for which a trend is sought; a is obtained by calculating the slope, the regression coefficient whose positive (+) or negative (−) signs express respectively increasing and decreasing trends over time x and b , a constant such as:

$$a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{N\sum x^2 - (\sum x)^2}; \quad b = \frac{N(\sum yx) - (\sum x)(\sum y)}{N\sum x^2 - (\sum x)^2}$$

Data and information from field investigations are used to analyze farmers' and

institutions' adaptation strategies to reduce the vulnerability of agricultural activities to environmental dynamics and effects.

2.7. Ways to Check How Well Adaptation Strategies Work

A multi-criteria analysis serves to evaluate the effectiveness of convenient strategies. It is a quantitative and more complex approach to assessing adaptation. It is a particularly useful tool for identifying adaptation assessment criteria (Seydou, 2020) and (Namodji et al., 2024). The criteria need not be measurable. Instead, adaptation options can be compared according to these criteria by assigning them an ordinal value (strong, medium, weak) or a cardinal value (1 to 5). Within the framework of this research, the criteria for evaluating the identified strategies have been defined and then weighted. Thus, two (2) evaluation criteria are used for the analysis, with each criterion weighted according to its importance in adaptation strategies. The second step consists of weighting the various adaptation options according to the evaluation criteria. The weighted average of a series of values is the number obtained by adding the products of these values by their coefficients and dividing the result by the sum of the coefficients. **Table 3** presents the adaptation effectiveness analysis matrix.

Table 3. Efficiency analysis matrix for convenient strategies.

	Financial criterion	Environmental criterion	Social criterion	Conclusion
Strategy	+	+	+	Long-lasting
	+	-	-	Low durability
	-	+	+	Low durability
	-	-	+	Low durability
	+	-	+	Low durability
	-	-	-	Unsustainable

Source: Namodji et al., 2024.

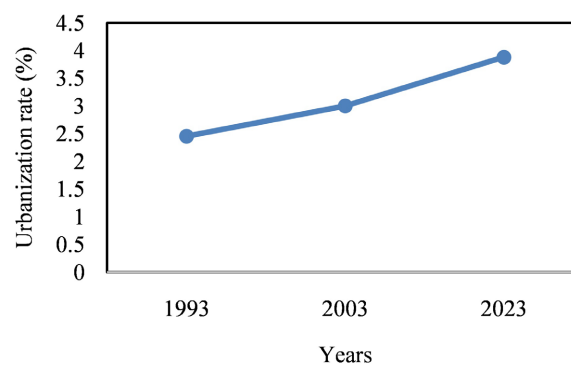
This table presents an analysis of the effectiveness of strategies through the lens of the three pillars of sustainable development: economic, environmental, and social. The first row of the table represents the ideal of performance. A strategy is considered truly effective and sustainable only when it manages to align all three indicators positively (+). This demonstrates that economic success should not come at the expense of the planet or humanity. This is the only scenario where the strategy is viable in the long term. For “Unsustainable” strategies, the table highlights four scenarios where the strategy fails to achieve sustainability despite some positive aspects. Indeed, a strategy that generates only economic profit is considered “unsustainable.” Without social support or environmental respect, it risks regulatory sanctions or social rejection. Even if a strategy is exemplary from a social and environmental perspective, the lack of economic viability (the negative sign) ultimately dooms it, as it cannot be self-financing. Whether it's a purely so-

cial success or an economic/social mix devoid of ecological considerations, the absence of even one pillar weakens the entire structure. The “Unsustainable” Strategy exemplifies this absolute failure. A strategy that destroys economic value, degrades the environment, and damages the social fabric is a completely bankrupt strategy that threatens the very survival of the farm. Long-lasting strategies are effective.

3. Results and Discussion

3.1. Town Planning Rate between 1990 and 2023 in the Municipalities of Aplahoue and Djakotomey

The urban growth rate improved between 1993 and 2023. The rate varies from 2.45% in 1993 to 3.88% in 2023, a rise of 58.36% (Figure 2).



Source: INStAD data processing, 2024.

Figure 2. 1990 to 2023 Urbanization Rate in the Municipalities of Aplahoue and Djakotomey.

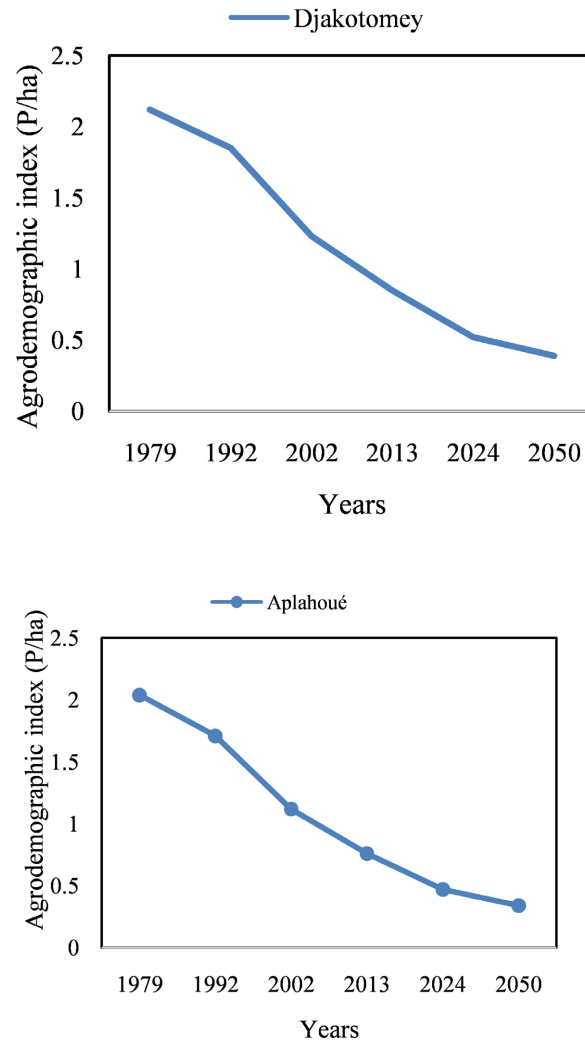
Urban expansion often encroaches on agricultural land, mainly fertile land near cities. This shrinks areas available for subsistence farming, sometimes compelling farmers to relocate farther from markets or abandon their land. Cultivated land loss is mainly due to plot splitting, the scale of the land market, and urban expansion.

3.2. Agro-Demographic Index in the Municipalities of Djakotomey and Aplahoue

The agro-demographic index aims to quantify population pressure on agricultural land. The agro-demographic index for the municipalities of Djakotomey and Aplahoue shows a decline from 1979 to 2050. It dropped by 81.60 and 83.33 percent in the municipalities of Djakotomey and Aplahoue, respectively. A resident of Djakotomey had 2.12 hectares of land in 1979. By 2050, population growth will have reduced this area to 0.39 hectares. However, a single inhabitant of Aplahoue had only 2.04 hectares in 1979 and will have 0.34 hectares in 2050 (Figure 3).

As the Agro-Demographic Index is below 0.5 ha/capita, it shows that agricultural land is under threat. There is therefore significant population pressure on

the land, pointing to low land resources per agricultural capita. Land scarcity fuels tensions and disputes between individuals, families, and communities, exacerbating land insecurity. Customary land rights are often challenged by modern rights, creating ambiguities that are prone to conflict. Fewer people share the same amount of land (or less land), and the average size of plots is decreasing. This leads to plots becoming fragmented, making farming less efficient.



Source: Calculation results, January 2025.

Figure 3. Changes in the agro-demographic index in the municipalities of Djakotomey and Aplahoué.

3.3. Land Tenure Security and Plot Splitting Rates in the Municipalities of Aplahoué and Djakotomey

It results in that 57% of villages are areas with low land tenure security, 25% have medium security, and 18% are areas with high land tenure security (**Figure 4**).

Land tenure insecurity is relatively high in the municipalities of Aplahoué and Djakotomey. Likewise, land splitting rates have increased exponentially between

1990 and 2024. In fact, plot splitting rates have risen from 32% in 1990 to 81% in 2024, with a rate of increase of 153.12% in the municipality of Djakotomey. In contrast, plot splitting rates rose from 27% in 1990 to 86% in 2024, with an improvement rate of 218.51% in the municipality of Aplahoue (Figure 5).

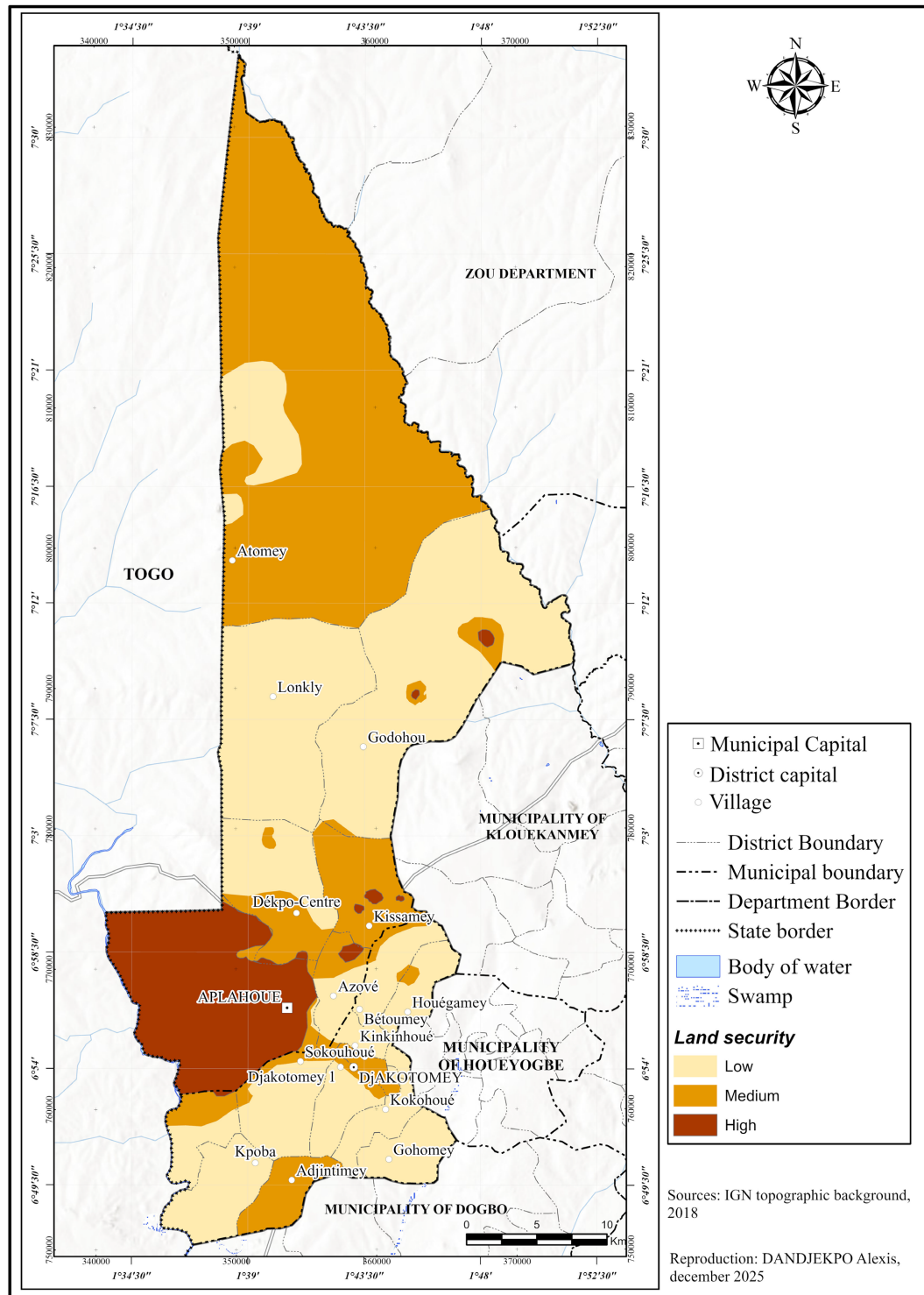
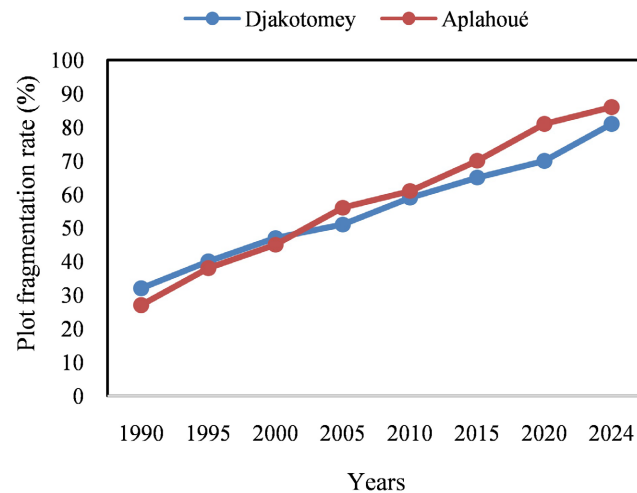


Figure 4. Land tenure security in the municipalities of Aplahoue and Djakotomey.



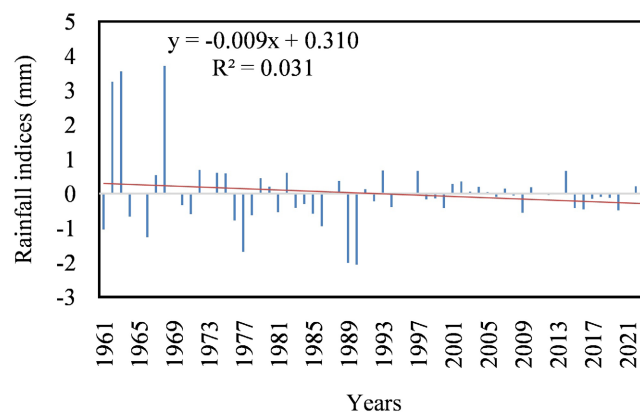
Source: Fieldwork calculation results, January 2025.

Figure 5. Plot splitting rates in the municipalities of Djakotomey and Aplahoué.

Thus, land splitting is higher in the municipality of Aplahoué. Inheritance leads to excessive division of land, making farming less efficient. New generations divide the land among their heirs, reducing the size of individual plots. Higher rural population growth and urban expansion reduce land availability, forcing farmers to expand production on smaller plots. The purchase or sale of small plots of land also fuels splitting.

3.4. Interannual Rainfall Variability Analysis between 1961 and 2023

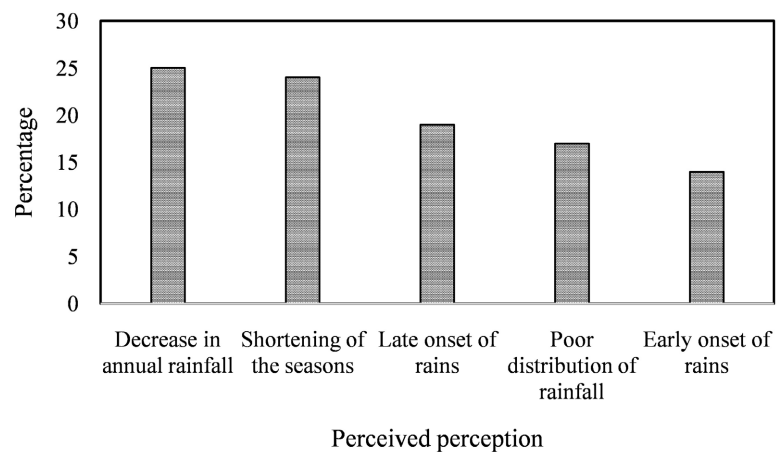
Rainfall analysis from 1961 to 2023 shows a downward trend. The R² coefficient of determination is very low (below 50%), indicating that a linear downward trend in rainfall levels cannot be concluded for recent years. The indices range from -2.05 to 3.72 over the study period (1961-2023) (**Figure 6**).



Source: Meteo Benin, 2024.

Figure 6. Standardized precipitation index trends in the municipality of Djakotomey from 1961 to 2023.

Deficit years are more common during this phase, pointing to the onset of rainfall recession in the 1990s. The second phase begins with the rainfall signal in 1991. Indices for the period 1991-2020 range from -0.55 to 0.65 . The second phase is marked by abnormal positive and negative anomalies. The period is characterized by 55% of dry years and 45% of rainy years. In addition, 3.22% of years are moderately dry and extremely dry, 12% are severely wet, 2% are extremely wet, and 79.56% are normal. The most severely rainy years are 1962, 1963, 1988, 1991, 2007, 2008, 2013, and 2019, and the most extremely rainy year is 1968. Moderately dry years have been 1961 and 1966. Extremely dry years have been 1989 and 1990. Rainfall levels in average years can satisfy crop water requirements and, as a result, produce a reasonable yield. Deficit years only benefit crops that require small amounts of water for their development. Excess years only benefit crops that require large amounts of water. Changes in rainfall patterns and annual totals already attest to rainfall variability in the research area. Severe rainfall deficits and surpluses raise significant challenges for agricultural production. Agricultural activities are highly sensitive to climate variability due to their hydro-climatic requirements. Reduced precipitation and increased temperatures tend to gradually increase aridity, thereby negatively impacting agricultural yields. Views focus on rainfall changes observed by local populations in the municipality of Djakotomey (Figure 7).



Sources: Field survey, July 2025.

Figure 7. Farmers' views on rainfall variations in Aplahoué and Djakotomey.

In fact, 25%, 24%, 19%, and 17% of respondents noticed a decrease in annual rainfall, shorter seasons, a late start to the rainy season, and poor rainfall distribution, respectively. Only 14% of these farmers reported early onset of rains in the commune of Djakotomey. Agricultural production is therefore more threatened by declining rainfall levels, shorter rainy seasons, late onset, and poor distribution of rainfall than by early onset of rains in the communes of Djakotomey and Aplahoué. Similarly, 67% of the survey area has an average exposure rate to flooding, 23% has a high exposure rate, and 10% has a low exposure rate. Furthermore,

there are differences in the level of exposure in both communes. Extended flooding suffocates plant roots, causing food crops (corn, cassava, cowpeas, etc.) to rot and die. The loss can be total or partial depending on the duration and height of the water. Flooded land remains unusable for a long time, disrupting the agricultural calendar and preventing timely sowing, which reduces the growing period of crops and exposes them to other hazards (late droughts). Populations develop convenient strategies to address this situation.

3.5. Land and Environmental Dynamics-Driven Adaptive Strategies

Endogenous adaptation strategies include soil fertilization strategies and adaptation strategies to land tenure and climate dynamics.

3.5.1. Soil Enrichment Strategies

Fertilization strategies aim to maintain soil productivity. They generally combine organic and mineral approaches. These include the use of crop residues, composting, crop rotation, and improved fallow. Thus, 32% of the respondent farmers in the municipalities of Djakotomey and Aplahoue use crop residues by burying straw and stalks. After harvesting (corn, cassava, etc.), plant residues are ploughed into the soil (buried or shallowly tilled) rather than burned. According to 45% of the respondents, compost improves soil structure and water retention capacity and provides slow-release nutrients. Meanwhile, the integration of livestock farming and agriculture (Integrated Livestock-Agriculture Management or ILAM) in the municipalities of Djakotomey and Aplahoue has made it possible to recycle animal waste (manure, poultry droppings). According to 33% of the respondents, manure, once matured, is an excellent organic fertilizer that provides nutrients and organic matter. Crops in the municipalities of Djakotomey and Aplahoue are part of a 2- to 5-year crop rotation because of the soil's fertility. Given soil infertility, crops are now subject to multiple rotations. Rotation refers to the succession of crops grown on the same field from one year to another. This technique helps restore soil fertility. These various techniques are beneficial to subsistence farming because they increase soil fertility and maintain it, resulting in higher yields. They also enable several crops to be cultivated on the same land instead of seeking other land for additional crops. This reduces costs and increases profits. According to 66% of the respondent farmers, these practices improve soil fertility, reduce pest and disease pressure, and optimize resource use. They help keep the soil healthy overall, making it more resilient to disturbances. Mixing legumes with grains boosts the nitrogen content of the soil and cuts down on fertilizer needs. Land pressure means that fallow periods are often too short. 38% of the respondent farmers in the municipalities of Djakotomey and Aplahoue use improved fallow practices. This technique consists of leaving the land fallow for a shorter period (1 to 3 years) by planting leguminous or shrub species that improve the soil (*Mucuna pruriens*, *Acacia auriculiformis*, *Cajanus cajan*-pigeon pea). The main objective is to quickly restore and improve soil fertility and produce other ecological and eco-

nomie benefits. These plants fix atmospheric nitrogen in the soil, improve its structure with their deep roots, and, once buried or left in place, enrich the soil with organic matter and nutrients. Improved fallow is adopted in different ways in the municipalities of Djakotomey and Aplahoue. These are short-term fallows (1 to 2 years) that are ideal for areas with high land pressure where long fallows are no longer possible, tree fallows, or agroforestry fallows. The latter consists of integrating nitrogen-fixing trees into plots, which can be regularly pruned to provide biomass to the soil. Faster than natural fallow, improved fallow allows land to be cultivated sooner. Heavy plant cover protects the soil from rain and wind. It improves the soil's texture, water storage, cation exchange capacity, and lowers the need for synthetic nitrogen fertilizers, which saves farmers money. Some improved fallow species are good at competing with weeds. Better fallow plants (e.g., pigeon peas, cowpeas) can produce edible seeds or fodder. Improved fallow enables more sustainable land use, reducing the need to clear new plots.

3.5.2. Climate and Land Use Strategies

Endogenous adaptation strategies include crop association, crop rotation, alteration of the agricultural calendar, repeated and staggered sowing, increased planting, development of low-lying areas, reorganization of the agricultural calendar, use of improved seeds, irrigation techniques, conversion to other economic activities, and the organization of prayer sessions. 89% of the respondent farmers use crop rotation techniques to address the problem of insufficient arable land caused by land issues and to maximize the profitability of the limited space available to them. Indeed, crop combinations enable several crops in a single plot to be sown. They also make it possible to harvest several crops simultaneously from the same area, thereby reducing production costs. They also offer opportunities to guarantee a minimum harvest at the end of the agricultural season. The main advantages of crop combinations include: better use of resources; reduced impact of insects and weeds; improved nitrogen levels with legumes; greater yield stability; crop diversification; and increased farm income. Producers are forced to combine several crops to avoid losing the entire harvest (**Photo 1**).



Shooting: Dandjekpo, June 2025.

Photo 1. Corn and cassava farming in Aplahoue.

The benefits of this practice are that it maximizes production and reduces the uncontrolled growth of weeds. The greater the number of crops, the more difficult it is for weeds to grow. However, such a practice is not without consequences, as it carries risks related to water shortages during the vegetative cycle of the various crops grown together. Crop rotation is a fundamental agronomic strategy that consists of organizing crop succession on the same agricultural plot over several years, according to a specific and planned order. Unlike simple rotation, which can be more flexible, crop rotation involves a structured long-term plan that aims to optimize soil fertility, manage pests, and maximize agricultural productivity in a sustainable manner. According to 45% of the respondent farmers, implementing good crop rotation is essential (**Photo 2**).



Shooting: Dandjekpo, June 2025.

Photo 2. Corn and cowpea crop rotation in Djakotomey.

Effective crop rotation involves several key principles to address local challenges. It avoids growing the same plant family on the same plot for several years in a row. This breaks the life cycles of pests and diseases specific to certain families and diversifies the nutrients taken from the soil. Farmers substitute cereals (corn, sorghum) with legumes (cowpeas, peanuts, soybeans) and roots/tubers (cassava, yams). They also alternate root systems, integrating deep-rooted crops with shallow-rooted crops. Cassava has deep roots, while corn and cowpeas have shallower root systems. This alternation helps to explore different depths of the soil for nutrients and improve the overall soil structure. **Kate (2016)** shows that practices such as crop rotation involving legumes, mineral fertilizer application, direct grazing, crop residue return, rotational grazing of cattle, the Zia technique, half-moon technique, and stone cordons are adaptation practices developed by producers. The implementation of the integrated crop-livestock farming development project will significantly contribute to strengthening the resilience of producers in the municipality of Banikoara.

Ogouwale (2013) notes that farmers are aware of natural ecosystem destruction, which is reflected in significant income declines, and are developing some envi-

ronmental conservation strategies such as practicing “Mucuna” fallow, planting and using improving species.

Crop rotation allows for the supply and maintenance of organic matter. After growing corn, sow cowpeas or soybeans, whose residues will enrich the soil with nitrogen and organic matter. According to 21% of the respondents, it is highly beneficial to include a period of improved fallow (with Mucuna) in the crop rotation. Crop rotation allows successive crops to vary their nutritional requirements, preventing the depletion of a specific element in the soil. Incorporate “improving crops” (legumes) that fix nitrogen and “depleting crops” that remove a lot of nutrients. Given the increasing climate disturbances, farmers adopt adaptation strategies to ensure food security and resilience for their populations. These disturbances include irregular rainfall, extended droughts, floods, and rising temperatures, which directly impact agricultural yields and livelihoods. 57% of the respondent households in the municipalities of Djakotomey and Aplahoue cultivate low-lying areas for rice and vegetable farming. Lowlands are naturally wetter areas that can be developed for water-resilient crops such as rice or off-season vegetable crops, providing a source of income and food when plateau lands are less productive. Two types of lowland development have been identified: traditional and modern developments. Traditional methods involve digging trenches to bring water by gravity to where it is needed and building small dams to keep the water in the rice field. This type of infrastructure is, in fact, quite archaic but allows the water supply for rice to be regulated. Unfortunately, it is quite laborious and requires frequent maintenance. In addition, this type of development has its flaws but is still beneficial because it requires very little knowledge to implement. On the other hand, modern developments include basic developments and those with total water control. In the opinion of 64% of the respondents, basic infrastructure is less expensive and requires less investment, knowledge, and maintenance than infrastructure with complete water control, described as heavy. The techniques in modern infrastructure acquired by producers are the result of several training courses on basic developments as part of the development of the rice sector in Aplahoue. These are developments aimed primarily at facilitating their adoption by farmers, with small-scale irrigation as the key benefit. However, traditional techniques are passed down from generation to generation and form part of the farmers’ own endogenous knowledge. Likewise, the actual development costs fall within a basic range. The average cost of the development work carried out is between 75 and 100 CFA francs per hectare. Improved seed varieties are chosen for their high yields, disease resistance, and drought tolerance, giving them a better chance of success in unpredictable weather. Short-cycle varieties are better suited to the shorter rainy season. This strategy has led to the departure from long-cycle seeds in favor of new seeds with a shorter vegetative cycle. Short-cycle corn, with a cycle of 65 to 70 days depending on the specific richness of the soil, is chosen by 92% of the respondents in order to boost yields. Farmers also have access to certified cassava seeds that are recognized for their resilience in the research arena. As a result, the new seeds are readily adopted by producers despite high water

requirements and the rigorous technical monitoring needed for these new crop varieties offered by ATDA Pôle 5 agents. For example, the new maize (*Zea mays*) seeds offered to producers include IZEE-W-SR (ODE-TUWE), which lasts 65 to 70 days, and PIRSABAK, which lasts 90 days. Moreover, 78% of the rice farmers have switched from the old varieties to new ones that are more resistant to drought and lodging. These include varieties such as ARCCU 3Fa7-L16P5-B-B-B3(R77) and WAB368-B-2-H2-HB(R56). According to [FAO \(2024\)](#), farmers' adaptation options to respond to weather threats include planting early-maturing varieties to avoid hot periods during the reproductive season, planting heat-tolerant varieties that are less sensitive to higher temperatures when they occur, or switching to different tree species that are more tolerant of or even prefer warmer conditions. [Djohy et al. \(2015\)](#) point out that multiple and mostly negative consequences of human-induced climate change are discussed in the ad hoc information sheet. Humans are also developing multiple responses to address the problem of climate change. These range from individual, voluntary contributions to measures envisaged at the global level, whether imposed or negotiated. Depending on the perspective, approach, and level of intervention, we may refer to climate policy, climate protection measures, climate risk management, or climate change strategies.

Market gardening is a crucial part of subsistence farming in the towns of Djakotomey and Aplahoue. The veggies grown in these gardens are vital for keeping farm families' diets balanced, adding to the basic grains and tubers. They provide important vitamins, minerals, and fiber. Fresh vegetables are in high demand in local markets and enable farming families to generate quick and regular income to cover their non-food needs, according to 62% of the respondents. It is often one of the most profitable activities for smallholders. Due to its intensive nature, market gardening generates significant income from very small plots, including low-lying areas that are often developed specifically for this purpose. This is particularly relevant in contexts where land pressure is high and access is limited. Farmers who grow vegetables generally keep their rain-fed food crops (corn, cassava) for their own consumption, while using vegetable farming as a source of additional income and to improve their family's diet. This strategy diversifies livelihoods within smallholder farming. Smallholder market gardeners often use techniques based on local inputs such as compost or manure, as part of a sustainable agriculture approach. Thus, despite the strong commercial component of market gardening, it is fully aligned with the improved and diversified subsistence farming approach adopted by smallholders in the municipalities of Djakotomey and Aplahoue, which aims to ensure both self-consumption and income generation for farming families. Farmers have implemented irrigation methods that involve watering crops during rainy season droughts using water stored in small reservoirs built in the fields. This strategy helps farmers keep their crops hydrated. Irrigation is a key factor in boosting vegetable production. Several methods are used on vegetable farms. These methods involve increasingly high levels of equipment. Watering systems identified include manual and semi-motorized watering. Women in the municipalities of Djakotomey and Aplahoue tend to choose to trade agri-

cultural products (52%). As for men, they engage in motorcycle taxi activities (34%), small ruminant and poultry farming (27%), charcoal production (31%), the sale of adulterated gasoline (43%), rural exodus (15%), and migration to Togo and Nigeria (23%). The expansion of this activity impacts the environment. Indeed, the uncontrolled felling of trees for charcoal production disrupts the micro-climate, which in turn affects climate variation.

People organize traditional ceremonies to ward off bad luck and limit the damage caused by climate change (delayed onset of rains, false starts in rainfall, rainfall disruptions, flooding during the growing season). These rituals are organized based on farmers' perceptions of climate change. Indeed, uneducated farmers perceive environmental dynamics as natural and divine, and therefore believe that humans can do little more than invoke the mercy of God and the spirits of their ancestors. Thus, given the climatic difficulties, i.e., the delay in the rainy season, there are pockets of drought, false starts, etc. As well, 53% of the respondents call upon the deities Ogou, Sakpata, Hevioso, etc., to invoke rain. However, people believe that these ceremonies are not as effective as they used to be because of how often the rules are broken and fewer people practicing due to the imported religions (Christianity and Islam) (Christianity and Islam). They also pray in churches and mosques to ask for divine protection from the harmful effects of floods.

3.5.3. Farmers' Adaptation Strategies Work

This is based on information collected from local communities on the different strategies developed to cope with climate change. This is expressed in three distinct categories: economic, social, and environmental. **Table 4** shows that 41.66% of the strategies developed by farmers are not very sustainable, while 58.34% are sustainable.

Table 4. Analysis Matrix for effective strategies.

Expanded Strategies	Aspects Financial aspect	Social aspect	Environmental aspect	Conclusion
Altering sowing dates	+	-	+	Low durability
Crop grouping	+	+	+	Long-lasting
Repeated and staggered sowing	-	+	+	Low durability
Improved fallow	+	+	+	Long-lasting
Altering planting patterns	+	+	-	Low durability
Floodplain management	+	+	-	Low durability
Crop rotation	-	+	+	Low durability
Crop rotation	+	+	+	Long-lasting
Improved seed use	+	+	+	Long-lasting
Watering techniques	+	+	+	Long-lasting
Broadening economic activities	+	+	+	Long-lasting
Group prayer organization	+	+	+	Long-lasting

Source: Field work, May 2025.

In short, measures such as changing sowing dates, modifying crop patterns, repeated and staggered sowing, lowland development, and crop rotation are not very effective. This means that additional targeted measures are needed to reduce farmers' vulnerability to environmental dynamics.

4. Conclusion

Flooded land in the municipalities of Djakotomey and Aplahoue remains impassable for extended periods, disrupting the agricultural cycle and preventing timely sowing, which shortens the growing season and exposes crops to other hazards (late droughts). Local communities develop appropriate strategies to address this situation. Fertilization strategies aim to maintain soil productivity. They generally combine organic and mineral inputs. These include the use of crop residues, composting, crop rotation, improved fallow, intercropping, crop rotation, altering the agricultural cycle, repeated and staggered sowing, expanding acreage, developing low-lying areas, rescheduling the agricultural cycle, using improved seeds, irrigation techniques, switching to other economic activities, and prayer sessions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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