Analysis of Rural Communities' Vulnerability Toto Climate Change in The Municipality of Bassila

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Abstract

Located in northwest Benin, the municipality of Bassila undergoes increasing exposure to climate change, characterized by rainfall variability, extended droughts, and frequent flooding. This study aims to assess rural communities' resilience to these hazards, based on a sectoral analysis of agriculture, animal husbandry, fishing, and water resources.

The research method combines a literature review, focus groups (50 participants in 4 districts), climate data analysis (1970–2023), and simulations from CMIP6 (SSP245 and SSP585 scenarios).

The results show a rainfall decrease of more than 100 mm per decade, minimal temperature increases of +1.25°C, and more extreme weather events. The agricultural sector has recorded yield losses of up to 47% for corn and 50% for yams, hitting 72% of households. Livestock farming is confronted with a decline of 40 to 60% in forage biomass, while fishing is experiencing a reduction from 15 to 45% in fish catches. At last, water availability is reduced from 40 to 70% in dry season, with water source contamination levels reaching 60% during floods. These results underscore the urgent need for integrated adaptation based on local capacity building, livelihood diversification, and inclusive resource management.

Keywords: Climate change, vulnerability, adaptation, Bassila, agriculture, breeding, fishing, water resources, Benin.

1. Introduction

The effects of climate change are increasingly evident worldwide, but they have particularly pronounced impacts in tropical regions, especially in developing countries. Climate disruptions are huge threats to livelihoods, food security, and social stability in rural areas where local economies mainly depend on rain-fed agriculture and natural resource use (Pelling, 2011; Huq &

Reid, 2007). The scientific literature agrees that current climate dynamics—including irregular rainfall, increased droughts and floods, and rising temperatures—are exacerbating the structural vulnerabilities of these areas (Berrang-Ford et al., 2011).

In Benin, the municipality of Bassila, located in Donga department, highlights these challenges. Like other areas in the Sudano-Guinean region, this municipality experiences increased climate variability, with significant effects on agricultural production systems, water availability, and conflicts over water use (MEPN-Benin, 2022). These disruptions weaken the adaptive capacities of rural communities, often characterized by limited access to institutional and technological resources.

Given this situation, several studies emphasise the need to transform socio-economic systems in order to adapt effectively to climate change (Pelling, 2011; Berrang-Ford et al., 2011). To this end, localised and collaborative approaches incorporating local knowledge seem to be strategic ways to make communities more resilient (Ensor & Berger, 2009). The inclusion of climate adaptation in land-use planning is seen as key to making sure responses are relevant, owned, and sustainable (Niang et al., 2016).

The municipality of Bassila drew up its Municipal Climate Change Adaptation Plan (PCACC) in 2024 as part of this approach. This strategic document aims to identify the specific vulnerabilities of the territory and propose mitigation measures based on rigorous and inclusive analysis. This article analyses the process of developing this plan, highlighting local adaptation dynamics, challenges encountered, and opportunities to strengthen territorial resilience to climate change.

2. Methodological Approach

This study is based on an integrated method that combines document analysis, gathering primary data and using historical and future climate data. The approach draws on guidelines developed by the Organization for Economic Cooperation and Development (OECD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) for incorporating climate change adaptation into local planning.

2.1 Literature review

A thorough review of scientific and gray literature has been conducted to establish a basic understanding of the local climate and socioeconomic context. The main sources include national climate reports (Meteo-Bénin), data from the General Population and Housing Census (RGPH4, 2013), and municipal planning documents, especially the fourth-generation Municipal Development Plan (PDC4) covering the period 2024–2028. This phase has enabled the identification of local dynamics, development priorities, and adaptation challenges already spotted at the regional level.

2.1.1 Primary data collection

To collect primary data, focus groups were organised in the four districts of Bassila (Alédjo, Bassila, Manigri, and Pénessoulou). These workshops brought together a total of fifty participants, evenly distributed across the four groups. The participants came from various socio-professional categories, such as farmers, herders, fishermen, as well as women, youth, and local leaders. The goal of the focus groups was to gather detailed perspectives on the climate risks perceived by the community, current adaptation strategies, and priorities for action at the local level.

The results from the focus groups revealed several common concerns among the participants, including challenges related to managing climate risks, a lack of resources for adaptation, and the need to strengthen awareness and training within the communities. The identified priorities for action include improving local infrastructure to withstand extreme weather events and integrating sustainable agricultural practices adapted to changing climate conditions.

2.1.2 Analyse climatique

The climate analysis is based on historical data from local weather stations from 1970 to 2023, provided by the National Meteorological Agency (Météo-Bénin). This includes annual and seasonal rainfall, as well as maximum and minimum temperatures. Also, climate forecasts have been made with four regional climate models (RCMs) from the CMIP6 program: EC-Earth3, HadGEM3, MPI-ESM, and IPSL-CM6A-LR. The simulations have been carried out based on two representative socioeconomic scenarios (SSP245 – intermediate trajectory, and SSP585 – pessimistic trajectory), with a view to predicting likely climate change by 2050.

2.1.3 Analysis methods

The analytical approach relies on a combination of quantitative and qualitative tools designed to assess the territory's climate vulnerability, prioritise adaptation measures, and ensure their validation by local stakeholders. Three additional methods have been used.

- *Vulnerability assessment*
The vulnerability assessment is based on the sensitivity matrix method developed within the framework of the LEG/UNFCCC guidelines (2004). This method enables the exposure of key sectors (agriculture, water resources and health) to the main climate risks identified in the municipality (drought, flooding, heat waves) to be assessed. Each sector-risk combination has been rated according to three components: sensitivity, exposure, and adaptive ability. A score between 1 (low) and 3 (high) has been assigned to each, then standardized. The final scores have been aggregated and classified into five vulnerability categories:
1 = very low vulnerability,
2 = low vulnerability,
3 = moderate vulnerability,
4 = high vulnerability,

5 = very high vulnerability

- *Multi-criteria prioritization analysis*

The identified adaptation strategies undergo a multi-criteria analysis (MCA) to rank them. This assessment relies on several weighted criteria, including: technical and institutional feasibility, expected impact on vulnerability reduction, relative implementation cost, environmental sustainability, and social acceptability. Each measure has been rated on a scale of 1 (low performance) to 5 (high performance), according to the established criteria. The summary of the scores has enabled the most relevant alternatives for the local context to be ranked.

- *Participatory authentication*

In compliance with community adaptation standards, the vulnerabilities and prioritization findings have been submitted for validation at two community meetings in the municipality of Bassila. These sessions involved all stakeholders in the process (local authorities, social-professional group representatives, community organizations, technical services). This step made it possible to adjust a number of proposals based on community feedback and to ensure local ownership of those guidelines (slide 1).

Plate 1: Focus group session in the municipality of Bassila
Pictures: Koumassi H., December 2025

3. Field of Study

3.1 Geographical location

The municipality of Bassila is located in northern Benin, between latitudes 8°35' and 9°28' North, and longitudes 1°29' and 2°14' East (Figure 1). It covers an area of 5,661 km², accounting for about 50.7% of the land area of the Donga department, making it one of the largest municipalities of the country.
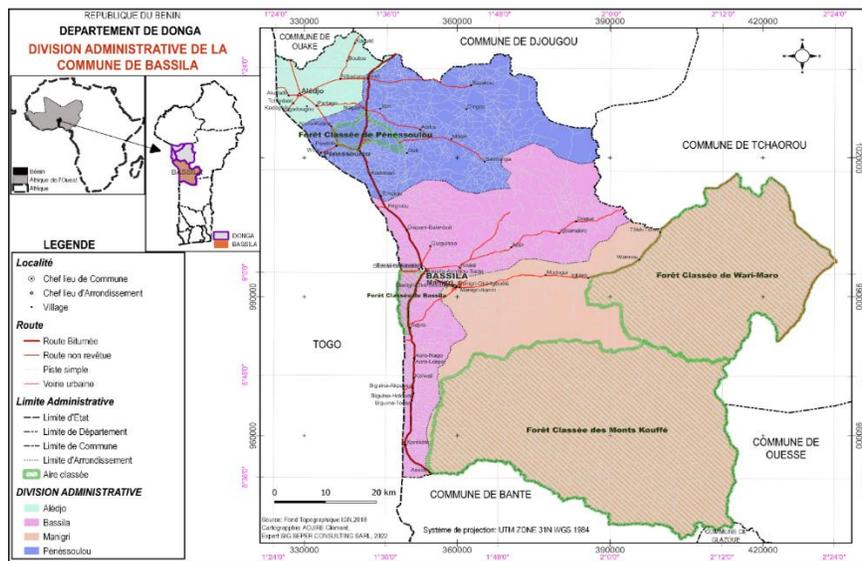

Figure 1: Geographical location of the municipality of Bassila

It shares its territorial boundaries with several administrative entities: northernly with the municipalities of Ouaké and Djougou, easterly with Tchaourou and Ouessè, southernly with Bantè and Glazoué, and westerly with the Republic of Togo, thus establishing an international border. This geographical location grants Bassila a strategic role both regionally and cross-border, mainly in terms of socio-economic interactions and migration dynamics.

The municipality's capital, the town of Bassila, is about 375 kilometres north of Cotonou, Benin's economic capital, and 87 kilometres south of Djougou, the region's main urban centre. The municipality is made up of four districts: Bassila, Alédjo, Manigri, and Pénessoulou, which include a bunch of villages with a strong agro-pastoral focus.

3.2 Physical features

Bassila area has a bunch of physical features, like different climates, soils, and water systems, which really affect farming and environmental issues.

3.2.1 Climate

The municipality is located in the dank Sudanian climate zone, featuring two main seasons: a rainy season from May to October and a dry season from November to April. (Figure 2).
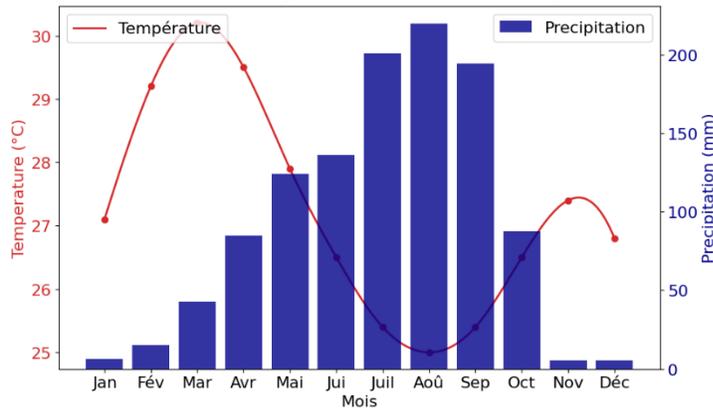

Figure 2: Ombrothermic diagram of the municipality of Bassila

The average annual rainfall recorded between 1985 and 2014 by the ASECNA station in Djougou is estimated at 1,277.6 mm. However, recent observances highlight increasing disruption to rainfall patterns, namely through delays in rainfall onset, extended dry spells, and early cutoffs, impacting the reliability of agricultural seasons.

3.2.2 Soils

The prevalent soils are tropical iron-rich and ferralitic, known for their moderate fertility and suitability for growing cotton, yams, corn, and other food crops. However, these soils are undergoing progressive degradation due to demographic pressure, extensive agricultural practices, deforestation, and increased water erosion, especially on steep slopes and unprotected land.

3.2.3 Hydrography

The municipality is crossed by several watercourses belonging to the Ouémé basin, including the Térou, Odola, and Adjiro rivers, as well as the Ouémé river itself. These water resources play a vital role in agricultural, pastoral, and domestic activities. Nevertheless, they are increasingly threatened by seasonal drying, silting, and declining flow rates, restricting their availability during peak periods and heightening tensions over their use.

3.2.4 Socio-economic features

The 2013 census showed that Bassila had 130,091 people, with an average annual growth rate of 3.96% from 2002 to 2013. This demographic trend is placing mounting pressure on natural resources and core social services.

The local economy is mainly based on agriculture, forestry, and livestock farming. Agriculture is the leading economic activity, involving 62.8% of the workforce. The major crops include maize, yams, cassava, sorghum, and cotton. Livestock farming is also a big deal, with about 8,737 households listed as farmers, while small-scale fishing goes on seasonally in ponds and rivers.

Conflicts between settled farmers and transhumant herders are common, especially during the dry season. These conflicts are fueled by water scarcity, shrinking pastures, and the lack of sustainable mechanisms for managing agro-pastoral areas.

4. Results

4.1 Signs of climate change

This provides an overview of climate change in the municipality. It details interannual and monthly variations, as well as temperature and precipitation trends observed in the municipality between 1970 and 2023.

4.1.1 Rainfall dynamics

4.1.1.1 Interannual rainfall change

The analysis of historical climate data (1970–2023) from Meteo-Benin indicates a general downward trend in annual precipitation in the municipality of Bassila, although this trend is subject to significant interannual change. This uncertainty is reflected in the irregular occurrence of rainy seasons, increased instances of dry spells during the season, and early endings to the rainy season, all of which negatively impact agricultural cycles.
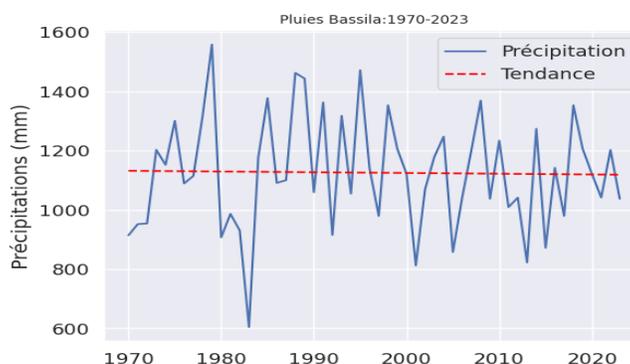

Figure 3: Annual rainfall trends for the period from 1970 to 2023
Source: Meteo-Bénin, 2024

Still, a closer look shows that rain amounts can really vary a lot from year to year within each decade. The last three decades (1980-1990, 1990-2000, and 2000-2010) had average annual

rainfall above 1,100 mm. The values registered for the earlier decades (1990-2000 and 2000-2010) are lower and represent the lowest annual rainfall recorded in the municipality (Figure 4).
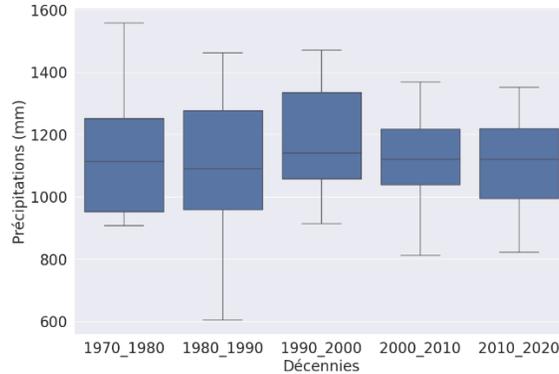
Figure 4: Annual precipitation changes per decade over the period from 1970 to 2020
Source: Meteo-Bénin, 2024

Prospective studies based on simulations from the Coupled Model Intercomparison Project Phase 6 (CMIP6) confirm this trend. The socio-economic scenarios SSP245 (intermediate trajectory) and SSP585 (pessimistic high-emission scenario) predict a significant decrease in average annual precipitation in the region by 2081–2100. However, this reduction would be coupled with an intensification of extreme events, with an expected increase in the frequency and severity of heavy rainfall episodes.

Though these extreme rainfall events are sporadic, they can cause flash flooding, jeopardizing key infrastructure, agricultural production, and rural mobility. Thus, the alternation between extended droughts and sudden floods constitutes a major double constraint for rural communities whose ability to adapt to this increasing variability is limited.

4.1.1.2 Intra-seasonal rainfall variability

Intra-seasonal trends in monthly rainfall have been observed over the period 1970 to 2023. Intra-seasonal trends in monthly rainfall have been observed over the period 1970 to 2023.
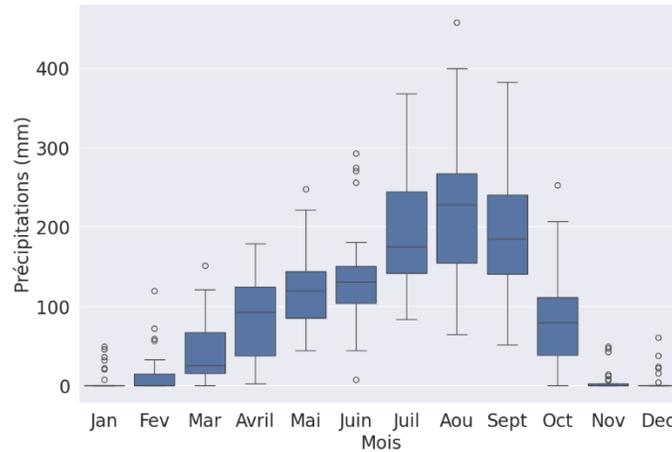
Figure 3: Monthly rainfall variation in the municipality of Bassila from 1970 to 2023
(Source: Meteo-Benin)

This figure shows that November, December, January, February, and March are pretty much dry, while the rainiest months are from June to September or even October, with June being the wettest month of all. It is worth noting that there is also some variability within each month throughout the study period (1970–2023).

4.1.2 Temperature Trends

Time series analysis of temperatures from 1970 to 2023 shows a clear upward trend in the municipality of Bassila. Over this period, maximum daily temperatures have increased by approximately +0.5°C, while minimum temperatures show a more significant increase of +1.25°C. This asymmetry in warming, with a more rapid increase in nighttime temperatures, is consistent with regional observations in West Africa.
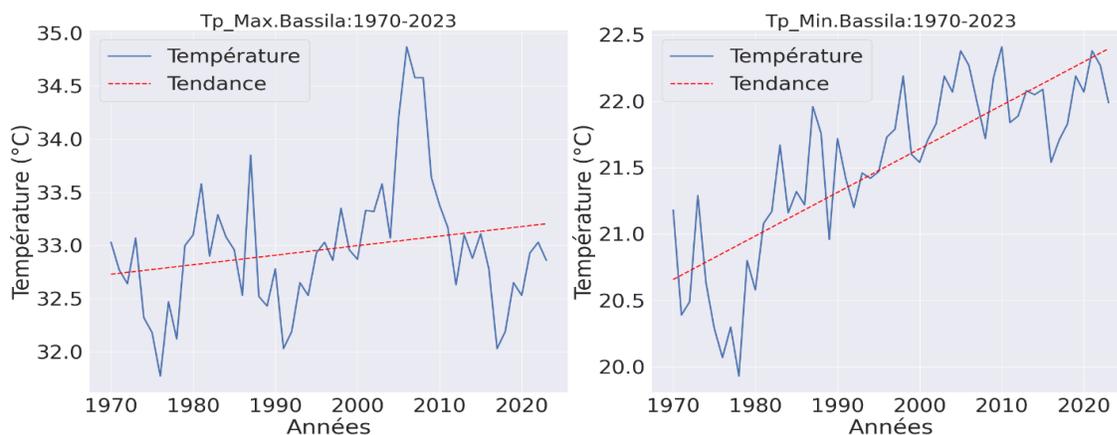

Figure 4: Maximum and minimum temperature variations in the municipality of Bassila from 1970 to 2023

Source: Meteo-Benin

Climate projections from CMIP6 regional models for the SSP245 and SSP585 scenarios foresee average temperature increases between +1.1°C and +2°C by 2100, depending on future emission levels. In fact, high night-time temperatures are likely to have significant effects on human health (increased heat stress and heat-related illnesses), as well as on agricultural and livestock productivity, by affecting plant life cycles, crop fertility, and livestock thermal comfort.

These changes increase evapotranspiration, reducing water availability for irrigation and domestic needs, and exacerbating tensions on water resources in a context already marked by declining rainfall.

4.2 Major climate threats

Besides the trends recorded in precipitation and temperatures, the municipality of Bassila is subject to an increasing variety of extreme climate risks, which greatly compromise the stability of local socio-ecological systems. The main hazards identified from community and climate data include:

- Intra-seasonal drought pockets, which result in long-term interruptions in rainfall during the agricultural season, impact the germination, flowering, and yield of food crops.
- Flooding caused by heavy rainfall on already saturated or degraded soil, leading to erosion, loss of agricultural land, infrastructure destruction, and water source contamination;
- Harsh winds, combined with early or late season storms, damage fragile homes, school facilities, and crops;
- Overheating, with recurring heat waves during the dry season, has harmful effects on human and animal health and increases soil water loss.
- The increasingly frequent early end to the rainy season shortens the growing season, thereby increasing the risk of unexpected agricultural losses.
- Wildfires, often caused by humans but exacerbated by drought conditions and dry vegetation cover, lead to biodiversity loss and contribute to the rapid decay of ecosystems.

The joint or successive occurrence of these hazards increases the vulnerability of local populations' livelihoods and impedes community-level anticipation and response capabilities.

5. Key sectors' exposure

The vulnerability of the main socio-economic sectors in the municipality of Bassila to climate hazards is assessed via a sensitivity matrix methodology, which assigns a vulnerability score (from 1 to 3) based on exposure, sensitivity, and adaptive capacity. The results highlight the different vulnerabilities of the following sectors:

5.1 Agriculture and food security

Farming is highly vulnerable to climate change, especially when the rainy season flattens out and there are pockets of drought during the season, which has been assigned a maximum vulnerability score of 3 out of 3 on the vulnerability index. Recent studies show that these disruptions can lead to yield losses of 18 to 47% for maize and 20 to 50% for yams, two major

crops in the municipality. These losses directly undermine food security, affecting up to 72% of farming households according to data from the Permanent Agricultural Survey (EAP, 2021). Furthermore, floods and heat waves, although classified as having a moderate level of vulnerability (score 2 out of 3), cause occasional crop losses of between 10% and 20% and exacerbate water stress, lowering water availability for irrigation by 15% to 25% in extreme years (CILSS, 2023).

5.2 Breeding

According to the National Framework for Climate Change Vulnerability Analysis (CNAV-CC, 2021), the livestock rearing is highly sensitive to the effects of extended droughts and extreme heat waves, with a high vulnerability score of 3 out of 3. These climatic stresses lead to a 40-60% reduction in available forage biomass (CILSS, 2022) and a decline of more than 50% in the quantity of water available for cattle in certain pastoral areas of northern and central Benin. This shortage of grazing resources leads to a significant decrease in land carrying capacity, equivalent to less than 0.3 tropical livestock units (TLUs) per hectare in heavily deteriorated areas (FAO, 2020). It also intensifies land conflicts between herders and farmers, with incidents reported increasing by nearly 70% between 2010 and 2020 (Land Working Group, 2021), especially during sensitive periods of food shortages and scarcity.

5.3Fishing

According to the National Framework for Climate Change Vulnerability Analysis (CNAV-CC, 2021), small-scale fishing in Térou, Odola, and other local rivers is highly vulnerable, with a score of 3 out of 3. This vulnerability is mainly due to the gradual drying up of watercourses during the dry season, which leads to a reduction of more than 50% in the average monthly flow in some rivers between January and April (DGEau, 2022). This is compounded by the migration and scarcity of fish species, including Clarias gariepinus and Tilapia spp., whose catches dropped by 15 to 45% between 2010 and 2020 (FAO, 2021; CRH-Benin, 2020). These disruptions associated with changes in the hydrological regime jeopardise the livelihoods of more than 3,000 artisanal fishermen in the coastal areas of the Collines department, slashing their seasonal earnings by 30 to 50% (INSAE, 2022).

5.4 Water resources

According to the National Framework for Climate Change Vulnerability Analysis (CNAV-CC, 2021), water resources are amongst the most exposed to climate hazards, with a maximum vulnerability score of 3 out of 3. The gradual drying up of rivers during the dry season leads to a 40 to 70% drop in average monthly flows on several watercourses such as Térou River, endangering access to drinking water for about 45% of rural households (DGEau, 2022; INSAE, 2021). This scarcity also affects agricultural practices, restricting the supply of irrigation water in peri-urban areas by 30 to 50% (CILSS, 2022). According to the National Water Information System (SNIE, 2021), over 25% of traditional water sources (wells, shallow boreholes) are flooded during the rainy season, with over 60% contaminated by microorganisms. These

hydrological disturbances heighten health risks (diarrhea, cholera) and increase conflicts over water use, especially in high-density human or agricultural areas.

6. Community-based actions

Rural communities in the municipality of Bassila have developed various adaptation strategies to mitigate the risks and preserve their livelihoods from the impacts of climate change. These initiatives, which stem from local dynamics, bear witness to the capacity for innovation and endogenous adaptation despite limited resources.

6.1 Agriculture

Farmers have started building dikes and ditches to channel rainwater and protect their fields from recurring floods. They have also been slowly switching to early-maturing, resistant crop varieties, like TZL COMP4C3 and EVDT-97 STR W. These varieties reduce the growing period and limit exposure to rainfall variability. Crop diversification, mainly corn-cowpea and cassava-corn combinations, is also a strategy aimed at improving the resilience of agricultural systems to climate variability.

6.2 Breeding

Livestock farmers have adapted their grazing practices by moving their herds to other watering spots that are less affected by drought and altering their migration schedules to better match when there is food available. These adjustments are meant to reduce heat stress on the animals and avoid conflicts with farmers over land use.

6.3 Fishing

Communities have implemented manual rehabilitation measures for water bodies in the fishing sector, including dredging and local management of ponds, in order to improve habitat conditions for fish species. In addition, controlled fish farming techniques in landscaped ponds make it possible to ensure more steady production that is less reliant on natural hydrological fluctuations.

7. Local initiative limits

A number of structural constraints hamper the effectiveness and sustainability of adaptation strategies implemented by rural communities in response to climate change.
Firstly, inadequate financial resources are major barriers to investment in resilient technologies and appropriate infrastructure, reducing the capacity to mainstream good agricultural, pastoral, and fisheries practices.

Unreliable weather warning systems and limited access to local climate data make it hard for people to predict hazards and plan their activities accordingly.

In addition, illiteracy rates are high, and people lack the skills to use modern technologies, which limits the rapid and effective adoption of technical innovations and best practices, hindering knowledge sharing and enhancing know-how among local actors.

Finally, poor coordination and collaboration between decentralized government services and rural communities hinder the coherent and integrated implementation of adaptation measures, thereby weakening the synergies needed to truly address climate challenges.

These shortcomings highlight the need to complement local initiatives with stronger public policies, increased technical and financial support, and appropriate institutional and community capacity building.

8. Discussion

Findings from this study show that local communities in Bassila are vulnerable because they rely a lot on natural resources and can't really adapt to more extreme weather. The downward trend in annual rainfall and the rise in maximum and minimum temperatures corroborate the climate projections from CMIP6, strengthening findings from previous studies conducted in other regions of Benin (INRAB, 2014). These climate changes are exacerbating soil deterioration, including water erosion and declining fertility, as well as water scarcity, which undermines agricultural and pastoral productivity.

Furthermore, ongoing conflicts between farmers and herders, heightened by increasing competition for water resources and grazing land, highlight the issues involved in land management and the need for inclusive and collaborative governance. These findings match the recommendations in the Municipal Climate Change Adaptation Plan (PCACC), which stresses the importance of strengthening local consensus-building mechanisms for sustainable natural resource management.

Despite being tailored to local constraints, identified community initiatives are restricted due to a perennial lack of financial, technical, and institutional resources. This gap hinders their ability to generate sustainable impacts and effectively strengthen community resilience. These findings are consistent with the analyses of Niang et al. (2016), who emphasise the importance of increased public policy support and local capacity building.

Unlike other municipalities in Benin, Bassila has similar vulnerabilities but is characterised by several worsening factors. Its border location encourages complex migration and pastoral dynamics, heightening land use tensions. Also, pastoralism, while traditionally suited to environmental constraints, leads to accelerated deforestation and ecosystem degradation, which worsens climate vulnerability.

These factors underscore the need to adopt sustainable land management, economic diversification, and institutional strengthening to improve the municipality's long-term resilience to the effects of climate change.

9. Conclusion

The municipality of Bassila is highly sensitive to the effects of climate change, with significant impacts on key areas such as agriculture, livestock farming, fishing, and water resource management. Though the adaptation strategies developed at the community level are relevant and innovative, they are still limited by financial, technical, and institutional constraints.

A number of key recommendations emerge from this study with a view to strengthening people's resilience:

- The expansion of appropriate water infrastructure, such as drains and reservoirs, to mitigate the effects of flooding and droughts.
- The promotion of climate-resilient agricultural varieties and the inclusion of agroecological practices that foster sustainable production systems;
- The implementation of effective early warning systems, along with training and awareness programs on climate issues;
- Strengthening local governance by creating inclusive committees to coordinate conflicts over natural resources and adapt to climate change.

Bassila's Municipal Climate Change Adaptation Plan (PCACC) provides an effective strategic framework through which these measures can be included in territorial planning. However, its success will largely depend on adequate funding and the sustained commitment of local stakeholders and national partners.

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