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# Climate Change and Forest Ecology in Benin (West Africa): Analysis of Mitigation Strategies and Recommendations

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## *ABSTRACT*

*Climate change, driven by rising temperatures, erratic rainfall, and human activities such as deforestation and shifting cultivation through burning, severely degrades the forest ecosystems of Benin. Despite interventions from the government and partners regarding reforestation, sustainable management and climate-resilient agriculture, forest loss, biodiversity decline, and ecosystem disruption persist due to funding gaps, weak law enforcement, socio-economic pressures and limited community engagement. The forests of Benin are essential for biodiversity conservation, livelihoods and climate regulation. It is crucial to understand how climate variables affect forest structure and biodiversity to assess the effectiveness of current mitigation strategies is essential for designing more resilient and locally adapted policies to safeguard ecosystems and support communities. A mixed methodological approach was used. The literature review focused on climate trends, forest cover and policies. A survey was conducted with 50 experts on climate impacts, biodiversity changes and policy effectiveness. An analysis of mitigation strategies was carried out to assess reforestation, agroforestry, community management, and National Action Plans (NAPs). Field observations were also made in the forests of Lama, Wari-Maro, and N'dali, along with a document on vegetation changes, invasive species, and community perceptions. Findings show strong links between climate variability and forest degradation, biodiversity loss, and species migration. Expert surveys revealed high perceived severity of impacts but low policy effectiveness. Reforestation survival rates are poor, agroforestry uptake is uneven, and NAPs are underfunded. Field visits confirmed canopy thinning, invasive species spread and wildlife decline, with communities reporting delayed rains and reduced yields. To mitigate the effects of climate change, certain actions must be taken, such as empowering communities in forest governance, prioritizing drought-resistant native trees in reforestation, developing agroforestry and climate-smart agriculture, strengthening inter-agency coordination, improving data systems, securing sustainable funding, and implementing educational programs to raise awareness about climate and conservation.*

***Keywords:*** *Climate Change , Forest Ecology, Mitigation strategies*

## I. INTRODUCTION

Climate change represents one of the greatest environmental challenges of our time. It refers to long-term alterations in temperature, precipitation patterns, wind, and other elements of the Earth's climate system [1]. This global phenomenon is primarily driven by human activities, particularly the burning of fossil fuels, deforestation, and intensive agricultural practices, which increase the concentration of greenhouse gases (GHGs) in the atmosphere [2]. As a result, the Earth is experiencing rising temperatures, more extreme weather events, changing rainfall patterns, and increasing sea levels, all of which have profound effects on ecosystems and biodiversity [3]. In Benin, a West African country with rich biodiversity and a strong dependence on natural resources, climate change has significant impacts on forest ecology [4]. Forests in Benin are not only vital for environmental balance contributing to soil fertility, water regulation, and carbon sequestration but also serve as a source of livelihoods for many rural communities [5]. However, changes in temperature and rainfall, combined with human pressures such as slash-and-burn agriculture, illegal logging, and bushfires, have led to forest degradation, loss of biodiversity, and disruption of ecosystem services [6]. These effects of climate change' are particularly evident in Benins southern and central regions, where humid and semi-deciduous forests are being rapidly transformed into savannah or degraded lands [7].

In response to these challenges, the Government of Benin, in partnership with international organizations and local stakeholders, has adopted several measures to mitigate the impact of climate change on forest ecosystems [8]. These include : Reforestation and afforestation programs, Promotion of sustainable forest management practices, Implementation of climate-smart agriculture to reduce pressure on forests and Integration of forest conservation into national climate strategies and Community-based forest governance initiatives [9]. Despite these efforts, the phenomenon of forest degradation persists. Several factors explain the continued vulnerability of Benin's forests to climate change [10]. First, many of the mitigation programs in Benin face limitations in funding, technical capacity, and long-term follow-up [11]. Secondly, socio-economic pressures such as population growth, poverty, and land insecurity continue to drive unsustainable land use practices [12]. Additionally, there is often a lack of coordination between policies at national and local levels, which limits the effectiveness of implemented strategies [13]. Furthermore, many communities lack awareness or incentives to adopt climate-resilient practices, and the enforcement of environmental regulations remains weak in many forest zones [14]. This research aims to fill these critical gaps by providing a detailed analysis of mitigation strategies to address climate change's impact on forest ecology in Benin.

Through empirical data and case studies from different forest zones, this work offers evidence-based recommendations to strengthen resilience and guide future policy interventions. Ultimately, the study seeks to contribute to national and regional efforts to safeguard Benin's forest ecosystems in the face of a changing climate.

## II. MATERIALS AND METHODS

This research on the impact of climate change on forest ecology in Benin was carried out using a mixed-methods approach, combining literature review, surveys, and field observations to ensure a comprehensive understanding of the phenomenon and the response strategies.

### a. Materials used

The research utilized a combination of qualitative and quantitative materials. These included : scientific literature on climate change and forest ecology in Benin; Climate data (1991-2020) ; device for taking picture of forest cover changes; structured questionnaires administered to forestry experts, local communities, and policymakers; official reports from environmental agencies; field observation equipment such as GPS, soil testers, and canopy measurement tools; and statistical software for data analysis.

According to Climate data, below are the values of the national summary stations and which vary acroos the country.

*Table N°1: Climate Data fo Benin (1991-2020)*

| N° | Parameters | Values and Zones |
|---|---|---|
| 1 | Mean annual temperature (1991–2020) | ~**27.5–28.0 °C** (Benin overall, country average). |
| 2 | Mean annual precipitation (1991–2020) | **~900–1,100 mm/year** for much of central/southern Benin; coastal zones and some southern areas up to ~1,300 mm; northern (Sahel-influenced) much lower and strongly seasonal. (See spatial maps on the World Bank portal for cell-by-cell values). |
| 3 | Seasonality (1991–2020 normals) | Southern Benin: bimodal rainy seasons (Mar–Jul and Sep–Nov). Northern Benin: single wet season (May–Nov) and dry Harmattan (Dec–Mar). |

*Source: National Meteorological Agency of Benin*

### b. Methods

#### 1. Literature Review

An extensive literature review was conducted to gather existing scientific knowledge on climate change and forest ecosystems in Benin. Sources included peer-reviewed journal articles, national climate and forestry reports, international databases (IPCC, FAO), and documents from the Ministry of Environment and Sustainable Development. This review provided insight into historical climate trends, forest cover changes, biodiversity impacts, and government responses.

#### 2. Survey of Experts and Researchers

A structured questionnaire was developed and administered to 50 researchers and practitioners specializing in forest ecology and climate change across universities, research institutions, and environmental NGOs in Benin. The survey captured their perspectives on the severity of climate impacts, observed changes in forest biodiversity, and the effectiveness of policy measures. Quantitative and qualitative data from the responses were analyzed using descriptive statistics and thematic content analysis.

#### 3. Analysis of Alternatives for Mitigation

Through both the literature review and expert survey, the study identified and analyzed various mitigation strategies adopted in Benin. These include:

- **Reforestation and afforestation programs**, notably through the National Reforestation Campaign
- **Agroforestry systems**, integrating trees into farmland to enhance resilience
- **Community-based forest management** involves local populations in sustainable practices
- **Climate-smart agriculture** promoted in forest-adjacent areas
- **National Adaptation Plans (NAPs)** and policy frameworks aimed at enhancing ecosystem resilience

#### 4. Field Observations

Field visits were conducted in selected forest zones across the country, including the Lama Forest, the Wari-Maro Forest, the N'dali Forest, and community-managed woodlands in the Atacora region. Observations focused on visible signs of ecological stress, such as reduced vegetation density, invasive species presence, and species migration. Interviews with local communities supplemented these observations, providing insights into local perceptions of climate impacts and traditional coping mechanisms. These three forests are located o the map of Benin below.

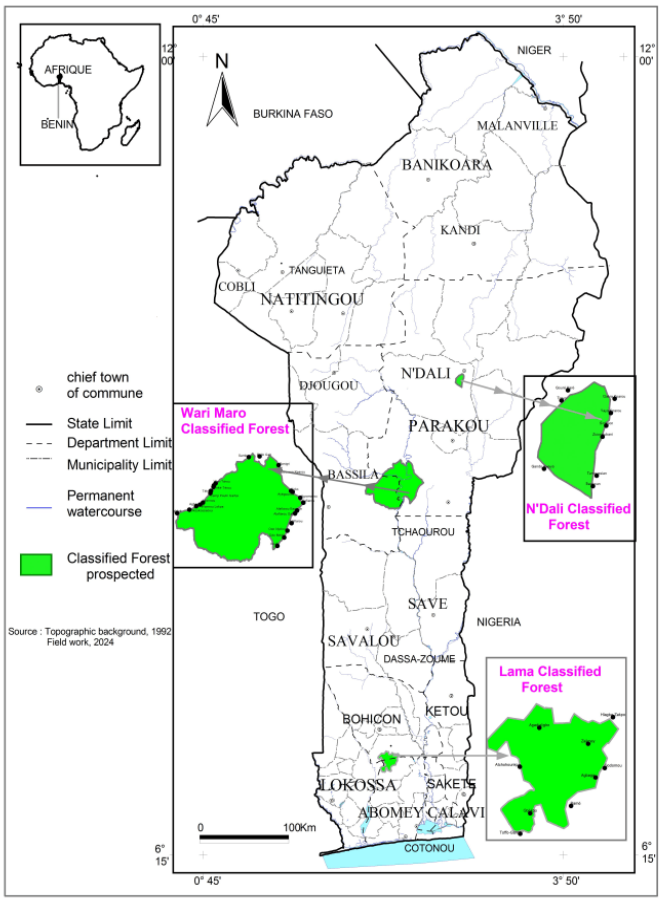


*Figure 1: Map of Benin's protected areas with the three classified forests*

## III . RESULTS

### 1. Key Findings from the Literature Review

The literature review confirmed a strong correlation between climate variability and degradation of forest ecosystems in Benin.

- **Rising Temperatures and Irregular Rainfall:** Historical climate data showed increasing average temperatures and erratic rainfall patterns over the past three decades, particularly in northern and central Benin [15].
- **Deforestation Trends:** National reports revealed a steady loss of forest cover, driven by both climate-related stress and anthropogenic pressures like agriculture and logging in Benin [16].
- **Biodiversity Loss:** Scientific literature and national inventories documented a decline in several forest-dependent species, especially those sensitive to microclimatic changes across Benin [17].
- **Policy Gaps Identified:** Despite the existence of climate-related policies of Benin, implementation weaknesses and a lack of coordination among stakeholders were highlighted [18].

### 2. Survey Results from Experts and Researchers

Analysis of the 50 responses from forestry and climate experts provided both quantitative and qualitative insights:

- **Perceived Severity:** 88% of respondents rated the impact of climate change on forest ecosystems as "high" or "very high."
- **Biodiversity Shifts:** Over 70% observed notable changes in species composition, including migration of some plant and animal species to higher altitudes or more humid zones.
- **Policy Effectiveness:** Only 40% considered current policies effective, citing inadequate funding, weak local engagement, and limited follow-up as major constraints.
- **Suggested Improvements:** Respondents emphasized the need for capacity building, decentralized forest governance, and integration of traditional knowledge into mitigation efforts.

### 3. Analysis of Mitigation Strategies in Benin

Benin has adopted several mitigation strategies to address the dual pressures of climate change and human activity on its forest ecosystems [19]. Among these, reforestation, agroforestry, community-based forest management, and the implementation of National Adaptation Plans (NAPs) stand out as central policy and practice tools. Each has achieved varying degrees of success, with challenges linked to funding, capacity, and governance.

#### a. Reforestation and Afforestation Programs

The National Reforestation Campaign has been the flagship initiative, planting millions of seedlings nationwide **[20]**. Reforestation targets environmental recovery by restoring degraded lands, enhancing carbon sequestration, and stabilizing soils [21]. However, survival rates of planted trees remain low, often under 40% due to insufficient post-planting care, water stress during prolonged dry seasons, and poor selection of species adapted to local microclimates [22]. Over-reliance on fast-growing exotic species, rather than native and drought-resistant varieties, has limited biodiversity benefits [23]. Technical follow-up, community participation in site maintenance, and integration of reforestation with broader landscape management are often lacking. Without these, the program risks becoming symbolic rather than transformative [24].

#### b. Agroforestry Systems

Agroforestry integrating trees into agricultural landscapes, offering a dual benefit: reducing deforestation pressure by increasing on-farm resources and improving resilience to climate stress through soil fertility enhancement, shade provision, and water retention [25]. In southern and central Benin, pilot projects have shown positive results, including increased crop yields and income diversification [26]. Yet adoption is uneven due to insecure land tenure, which discourages long-term investments, and limited farmer training on species selection and management [27]. Agroforestry scalability depends on policy reforms to secure land rights, access to seedlings, and market incentives for tree-based products. When implemented effectively, agroforestry aligns environmental sustainability with rural development goals [28].

#### c. Community-Based Forest Management (CBFM)

Community-Based Forest Management (CBFM) seeks to transfer management rights and responsibilities to local communities, fostering stewardship and accountability [29]. In regions like Atacora in Benin, community-managed forests have shown improved protection against illegal logging and bushfires, partly due to the integration of traditional ecological knowledge [30]. Nevertheless, many communities face constraints such as inadequate legal recognition of their rights, limited financial resources, and weak technical support [31]. Conflicts over resource access can undermine collective management [32]. Effective CBFM requires capacity building, equitable benefit-sharing mechanisms, and stronger institutional backing from government agencies to ensure communities can enforce rules and sustain management efforts [33].

#### d. National Adaptation Plans (NAPs)

Benin's NAPs provide a strategic framework for climate resilience, integrating forest conservation with broader adaptation objectives in agriculture, water, and energy. They promote ecosystem-based adaptation, policy harmonization, and capacity building. [34] On paper, NAPs are comprehensive, yet their operationalization is hindered by chronic underfunding, fragmented inter-agency coordination, and a lack of robust ecological monitoring systems [35]. Many planned actions remain donor-dependent, risking discontinuity when external financing lapses [36]. Moreover, data gaps, particularly on forest carbon stocks, species migration, and socio-economic impacts, limit evidence-based decision-making [37]. To improve effectiveness, NAPs require a stable domestic funding mechanism, integration of local-level priorities, and a results-based monitoring framework [38].

### 4. Field Observation Results

Direct observations in Lama Forest, Wari-Maro Forest, and Atacora revealed clear signs of ecological stress:

- **Vegetation Decline:** Notable thinning of forest canopies and reduced regeneration rates.
- **Invasive Species:** An increase in invasive plant species such as *Chromolaena odorata* was documented, especially in disturbed zones.
- **Wildlife Displacement:** Local community testimonies and tracking signs suggested a decline in key fauna like antelopes and certain bird species.

- **Community Perceptions:** Local populations reported delayed rainfall, reduced crop yields, and longer dry seasons as the most noticeable climate changes affecting forests and livelihoods.

The study confirmed that climate change is having a profound and measurable impact on forest ecology in Benin, manifested through biodiversity shifts, forest degradation, and increased vulnerability of ecosystems. While several mitigation strategies are in place, their effectiveness is undermined by policy and implementation gaps. Community involvement, improved governance, and investment in ecosystem-based adaptation are crucial to enhancing forest resilience in the face of ongoing climate stress.

*Photo 1: Thinned Lama Forest Canopy*

## IV. DISCUSSION

The study's findings highlight the complex and multifaceted nature of climate change impacts on forest ecology in Benin. Integrating scientific literature, expert surveys, and direct field observations enabled a comprehensive understanding of both the ecological transformations underway and the institutional responses being applied.

### 1. Ecological Stress and Forest Degradation

The literature and field data confirm that climate change is exerting substantial stress on forest ecosystems [39]. Increases in average temperatures and the growing unpredictability of rainfall patterns have led to longer dry seasons and reduced water availability, directly affecting forest health [40]. Field observations in the Lama, Wari-Maro, and N'dali forests revealed signs of declining vegetation density, increased soil dryness, and reduced species regeneration [41]. These ecological changes are further compounded by anthropogenic pressures such as illegal logging, slash-and-burn agriculture, and fuelwood collection. The combined effects contribute to accelerated forest degradation and fragmentation [42].

### 2. Biodiversity Shifts and Species Vulnerability

Survey responses from forest ecology and climate experts pointed to observable changes in species composition [43]. More than 70% of respondents reported a decline in biodiversity and the migration of sensitive species to cooler or more humid zones, particularly in northern Benin [44]. This aligns with global patterns where climate stress prompts species to alter their habitats or face extinction [45]. The increase in invasive species, noted during fieldwork, presents an added ecological threat, potentially displacing native flora and fauna and disrupting established ecosystem functions such as pollination and nutrient cycling [46].

### 3. Evaluation of Mitigation Strategies

The research identified key strategies implemented to address forest degradation. *Programs* such as the National Reforestation Campaign, agroforestry promotion, and climate-smart agriculture demonstrate political will and institutional engagement. However, the effectiveness of these initiatives remains mixed [47]. Reforestation efforts have been undermined by poor maintenance, low seedling survival rates, and limited community involvement [48]. While agroforestry practices have shown promise in integrating trees into agricultural systems, uptake remains low in certain regions due to land tenure issues and lack of farmer training [49]. Climate-smart agriculture is effective in reducing deforestation pressure but is not yet widely adopted [50]. The study also found that community-based forest management models, though successful in specific areas like Atacora, face challenges of limited resources and technical support. *Despite* the presence of National Adaptation Plans (NAPs), weak implementation frameworks and financial constraints restrict their impact [51].

### 4. Policy Gaps and Implementation Challenges

Although Benin has developed relevant policy instruments to tackle climate change, their execution remains inadequate [52]. Only 40% of surveyed experts considered the policies effective, citing bureaucratic inertia, limited funding, poor intersectoral coordination, and lack of reliable data for monitoring [53]. The results reveal a disconnect between national policy intentions and local-level realities, where forest users often lack awareness or access to adaptation support mechanisms. *Effective* forest governance thus requires stronger institutional coordination, capacity building, and community empowerment to bridge this gap [54].

### 1. Importance of Local Knowledge and Community Involvement

Fieldwork revealed that local communities possess valuable traditional knowledge and observations on climate patterns and ecological changes [55]. Accounts of communities such as delayed rainfall, disappearing species, and declining yields complement scientific findings and provide grounded perspectives on climate impacts [56]. This underscores the importance of participatory approaches that involve local stakeholders not only in forest management but also in designing and implementing adaptation strategies [57]. Local communities can act as both observers and custodians of forest ecosystems when adequately supported and included in decision-making processes [58].

## V. CONCLUSION

The study confirms that climate change is significantly degrading Benin's forest ecosystems through rising temperatures, erratic rainfall, biodiversity loss, and increased invasive species. Expert surveys and field observations highlight low policy effectiveness, poor reforestation survival rates, uneven agroforestry adoption, and persistent community vulnerability.

To address these challenges, the research recommends empowering local communities in forest governance, prioritizing native drought-resistant trees, scaling up agroforestry and climate-smart agriculture, improving policy coordination and data monitoring, securing sustainable funding, and expanding education programs. These actions are essential to bridge the gap between policy and practice and build climate-resilient forests.

## VI. RECOMMENDATIONS

Based on the observed impacts of climate change on forest ecology in Benin and the evaluation of current mitigation efforts, the following recommendations are proposed to strengthen resilience and promote sustainable forest management :

- Empower local communities through legal recognition, training, and resource allocation to manage forest areas. Their involvement enhances sustainability, promotes ownership, and integrates traditional knowledge into conservation practices [59]
- Reforestation efforts must prioritize native and drought-resistant species, ensure regular maintenance, and provide technical support to local actors [60] .
- Monitoring mechanisms should be established to evaluate survival rates and ecosystem recovery[61].
- Scale up agroforestry systems and climate-smart agricultural practices by improving land tenure security, farmer training, and access to financial incentives. This reduces pressure on forests while supporting livelihoods [62] .
- Establish stronger inter-institutional coordination to align forest, climate, and agricultural policies. Improve data collection and monitoring systems to track ecological changes and policy impacts effectively [63] .
- Mobilize national and international funding to support adaptation and forest resilience projects. Strengthen institutional capacities through training and technology transfer, especially at the local level [64] .
- Develop education and outreach programs targeting schools, farmers, and decision-makers to raise awareness on climate impacts and forest conservation [65].

These recommendations aim to close the gap between policy and practice, improve forest resilience, and ensure that climate adaptation strategies are inclusive, science-based, and locally grounded.

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