

Assessing the Impact of Climate Change on Biodiversity in Rural Areas of Senanga District, Zambia: AI-Powered Ecological Monitoring, Conservation Technology and Community-based Adaptation

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Abstract —Climate change is driving unprecedented biodiversity loss across sub-Saharan Africa, with cascading consequences for ecosystem services, agricultural productivity, food security, and community livelihoods. In rural areas of Senanga District, Western Province, Zambia, climate-driven changes in temperature, precipitation, and flood-drought cycles are progressively transforming ecological systems affecting fish populations in the Zambezi floodplain, woodland biodiversity in miombo and mulapo habitats, and the wild plant and animal resources upon which many community livelihoods depend. This article assesses the impact of climate change on biodiversity in rural Senanga District, situating findings within global scholarship on AI-powered ecological monitoring, remote sensing conservation technology, community-based natural resource management, and climate adaptation. Drawing on a mixed-methods survey combining community ecological knowledge documentation with remote sensing analysis and key informant interviews, findings confirm significant biodiversity losses across fish, woodland, and grassland ecosystems attributable to climate variability and associated land use change. AI-powered biodiversity monitoring systems, satellite-based habitat mapping, and community digital environmental stewardship platforms are identified as evidence-based conservation pathways. Policy recommendations are presented.

Keywords — *Climate Change, Biodiversity; Senanga District; Zambia; AI Ecological Monitoring; Conservation Technology; Community Adaptation; Ecosystem Services.*

1. Introduction

Biodiversity the variety of life forms and ecological relationships that constitute functional ecosystems underpins the ecosystem services upon which human communities depend for food, water, medicine, climate regulation, and spiritual and cultural meaning (Shanthi et al., 2025; Venice et al., 2025a). Climate change is driving global biodiversity loss at rates unprecedented in recent geological history, with tropical and subtropical African ecosystems among the most acutely affected due to their high biodiversity endemism, climate sensitivity, and limited adaptive capacity relative to the pace of climate change (Ashifa, 2021a; Vettriselvan et al., 2025b).

In Senanga District, Western Province, the Zambezi River floodplain system one of the most ecologically significant wetland ecosystems in southern Africa is experiencing profound climate-driven change: altered flood timing and intensity, expanded drought periods, and temperature increases that are disrupting the seasonal ecological rhythms upon which both biodiversity and community livelihoods depend (Vettriselvan & Anto, 2018; Kariveliparambil et al., 2026b; A S Aneeshkumar et al., 2015). AI-powered biodiversity monitoring technologies including satellite-based habitat mapping, acoustic biodiversity monitoring, citizen science biodiversity

recording platforms, and machine learning species identification systems offer transformative possibilities for systematic biodiversity assessment and conservation management at scales previously impossible in resource-constrained African conservation contexts (Venice et al., 2025b; Shanthi et al., 2025). This article assesses climate change biodiversity impacts in Senanga District and identifies technology-mediated conservation pathways.

2. Literature Review

2.1 Climate Change and Biodiversity in Sub-Saharan Africa

Sub-Saharan Africa's extraordinary biodiversity encompassing approximately 25% of global mammal diversity, 17% of bird species, and vast plant and invertebrate diversity faces disproportionate climate change threat relative to global averages (Shanthi et al., 2025; Venice et al., 2025a). Projected temperature increases of 2–4°C by 2100 under current emissions trajectories would drive range contractions, phenological mismatches, and local extinctions across multiple taxa with freshwater ecosystems and seasonal wetlands including the Senanga floodplain among the most vulnerable habitats (Ashifa, 2021a; Vettriselvan et al., 2025b). Changing precipitation patterns including more intense and shorter rainfall seasons interspersed with extended drought alter the flood pulse

dynamics that drive floodplain ecosystem productivity, fish recruitment, and the seasonal ecological processes that support both biodiversity and community fishery livelihoods (Venice et al., 2025a; Kariveliparambil et al., 2026b; A. S. Aneeshkumar et al., 2013). Land use change driven by agricultural expansion, deforestation for fuel wood and charcoal production, and resettlement associated with climate-induced displacement compounds direct climate impacts on biodiversity, fragmenting habitats, reducing wildlife corridors, and eliminating the refugia that species require to survive climate extremes (Vettriselvan et al., 2025b; Ashifa, 2022).

The interaction between climate change and land use change creates biodiversity loss trajectories that exceed the impacts of either driver operating alone making integrated climate and land use governance essential for effective biodiversity conservation (Shanthi et al., 2025; Vettriselvan et al., 2026a).

2.2 AI-Powered Biodiversity Monitoring

Artificial intelligence has transformed the possibilities for systematic biodiversity monitoring at ecologically meaningful spatial and temporal scales (Venice et al., 2025b; Akila et al., 2025). Machine learning image recognition systems trained on wildlife camera trap photographs can automatically identify species, estimate population densities, and detect behavioural patterns across thousands of camera hours enabling biodiversity monitoring at landscape scales without the prohibitive human labour costs of manual data processing (Venice et al., 2025c; Basha et al., 2025).

AI-powered acoustic monitoring systems that analyse soundscape recordings to identify bird, bat, amphibian, and insect species by their vocalisations provide continuous biodiversity assessment across habitats without requiring direct visual observation (Shanthi et al., 2025; Venice et al., 2025d).

Satellite-based remote sensing analysis using AI image processing detecting vegetation change, water body dynamics, land cover transitions, and habitat fragmentation from multitemporal satellite imagery provides landscape-level biodiversity habitat monitoring at scales from individual habitat patches to entire protected area networks (Venice et al., 2025a; Vasantha et al., 2025). Citizen science biodiversity recording platforms that aggregate community observations of plants, animals, and ecological events using AI-assisted species identification from photographs submitted through mobile applications engage local communities in biodiversity monitoring while generating scientifically valuable occurrence data at densities impossible through professional survey alone (Venice et al., 2025b; Swadhi et al., 2025a).

2.3 Community-Based Natural Resource Management

Community-based natural resource management (CBNRM) engaging local communities as custodians, managers, and beneficiaries of natural resources in their territories is well-established as an effective approach for integrating biodiversity conservation with community livelihood needs (Kariveliparambil et al., 2026a; Rasi & Ashifa, 2019). In the Senanga District context, CBNRM approaches that formalise the conservation stewardship role of communities in the Zambezi floodplain incorporating AI-powered monitoring tools, digital governance platforms, and sustainable use protocols offer a promising pathway for simultaneously protecting biodiversity and supporting the community livelihoods that depend on healthy ecosystem functioning (Venice et al., 2025a; Vettriselvan et al., 2026b).

2.4 Community Knowledge and Well-being

Traditional ecological knowledge the accumulated understanding of local ecosystems, species, seasonal dynamics, and ecological relationships held by community members through generations of direct interaction with their natural environment is a valuable and underutilised resource for biodiversity conservation and climate adaptation (Kariveliparambil et al., 2026a; Ashifa, 2022).

The erosion of traditional ecological knowledge through cultural change, educational system neglect, and generational disruption simultaneously reduces community capacity for ecological stewardship and eliminates a unique information resource for conservation science (Rasi & Ashifa, 2019; Kariveliparambil et al., 2026b). Digital documentation platforms that capture, preserve, and make accessible traditional ecological knowledge integrating it with scientific monitoring data in AI-powered conservation decision support systems represent a promising bridge between indigenous wisdom and contemporary conservation technology (Venice et al., 2025b; Vasantha et al., 2025).

3. Methodology

A mixed-methods descriptive survey was employed to assess climate change impacts on biodiversity in rural areas of Senanga District. Methods combined structured community ecological knowledge questionnaires, key informant interviews with traditional leaders and resource management officials, secondary analysis of available remote sensing data, and focus group discussions with fishing and farming community members (Kombo & Tromp, 2014; Orodho & Kombo, 2012). The sample comprised 80 community respondents, 12 key informants, and 4 focus groups. Remote sensing data from publicly available satellite imagery repositories were used to

document decadal vegetation and water body change in the study area.

4. Findings and Analysis

4.1 Community-Observed Biodiversity Change

Community respondents reported dramatic biodiversity declines across all taxonomic groups over the preceding decade. Freshwater fish species particularly commercially and nutritionally important species including tiger fish, bream, and catfish were reported as significantly less abundant by 88% of fishing community respondents, with 65% attributing decline to altered flood timing and shortened flood duration rather than overfishing alone. Woodland bird diversity was perceived to have declined significantly by 74% of respondents, with large mammal sightings increasingly rare in previously wildlife-rich areas (Shanthi et al., 2025; Kariveliparambil et al., 2026b).

4.2 Remote Sensing Evidence

Analysis of available satellite imagery indicated a 28% reduction in permanent water body extent and a 35% reduction in flood inundation area in the study zone over the preceding decade changes consistent with climate-driven reductions in Zambezi flood pulse magnitude documented in regional hydrological research. Woodland cover reduction of approximately 22% was detected, with the majority attributable to agricultural expansion and deforestation rather than climate-driven die-back alone (Venice et al., 2025b; Shanthi et al., 2025).

4.3 Ecosystem Service Impacts

Community respondents reported significant impacts on ecosystem service provisioning: mean fish catch declined by 45% according to community estimates; medicinal plant availability declined significantly according to 78% of traditional health practitioners interviewed; and grassland productivity for livestock grazing was reported as declining by 65% of livestock-keeping households (Ashifa, 2022; Kariveliparambil et al., 2026a).

4.4 Community Adaptation Responses

Community adaptation responses included livelihood diversification away from fishing toward agriculture (62% of households), adoption of shorter-cycle crop varieties better suited to shortened rainfall seasons (45%), and seasonal labour migration to urban areas during ecological productivity troughs (38%). AI-powered climate advisory services and digital biodiversity monitoring tools were unknown to community members indicating significant

unmet potential for technology-assisted conservation and adaptation (Venice et al., 2025a; Vasantha et al., 2025).

5. Discussion

The findings confirm rapid and community-experienced biodiversity decline in Senanga District driven by the interaction of climate change and land use pressure on the Zambezi floodplain and associated ecosystems. The community ecological knowledge documented in this study provides valuable baseline information that scientific monitoring alone has not captured underscoring the importance of integrating traditional knowledge with AI-powered monitoring in Zambian conservation governance (Venice et al., 2025b; Kariveliparambil et al., 2026a). Citizen science biodiversity recording platforms that engage Senanga communities in systematic ecological observation with AI-assisted species identification could transform community members from passive observers of biodiversity decline into active conservation monitoring partners (Venice et al., 2025c; Swadhi et al., 2025a).

6. Conclusion and Recommendations

Recommendations: (1) establish AI-powered biodiversity monitoring networks in Senanga floodplain using camera traps, acoustic monitors, and satellite imagery (Venice et al., 2025b; Shanthi et al., 2025); (2) develop citizen science biodiversity recording platforms engaging community members in ecological monitoring (Venice et al., 2025c; Swadhi et al., 2025a); (3) formalise community-based natural resource management with digital governance platforms (Kariveliparambil et al., 2026a; Venice et al., 2025a); (4) document and integrate traditional ecological knowledge into AI conservation decision support systems (Venice et al., 2025b; Vasantha et al., 2025); and (5) develop AI-powered climate adaptation advisory services for fishing and farming communities (Venice et al., 2025d; Arockia et al., 2025).

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