Assessing the Impact of Climate Change on Liberia's Agricultural Sector and Strategic Adaptation Approaches

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ABSTRACT

Climate change poses a critical threat to agricultural systems and food security worldwide, with particularly acute impacts in post-conflict nations like Liberia. This systematic literature review examines the impacts of climate change on Liberia's agricultural sector and identifies context-appropriate adaptation strategies. We analyzed 72 peer-reviewed articles and institutional reports (2011-2024) addressing agricultural productivity under climate change in Sub-Saharan Africa and West African contexts applicable to Liberia. The review synthesizes evidence on temperature increases, rainfall variability, drought stress, flooding, and pest proliferation, all of which significantly reduce crop yields in tropical agricultural systems. Key adaptation strategies identified include: crop diversification with drought- and flood-tolerant varieties, improved water management, adjusted planting calendars based on climate forecasts, agroforestry systems, conservation agriculture, integrated pest management, enhanced climate information services, and soil fertility management. These strategies, drawn from regional experiences and adapted to Liberia's post-conflict context, offer pathways to enhance agricultural resilience. However, significant research gaps remain regarding Liberia-specific climate impacts and the effectiveness of adaptation interventions under local conditions. This review provides evidence-based recommendations for policymakers, development partners, and researchers to support climate-resilient agricultural development in Liberia.

Keywords: agriculture; climate change; Liberia; food productivity; adaptation strategies; post-conflict recovery; systematic review; West Africa

INTRODUCTION

Climate change has emerged as one of the most pressing global challenges of the 21st century, with profound impacts on agricultural systems and food security. Rising sea levels, biodiversity loss, diminishing soil moisture, and the proliferation of plant pathogens represent well-documented consequences of anthropogenic climate change (Singh et al., 2019; Heilmeier, 2019; Dorji et al., 2020; Pandey and Choudhary, 2019). Global food security faces increasing threats from climate variability, with significant disruptions in crop productivity observed across multiple regions (Ruminta, 2016). Ray et al. (2019) found that climate change has already begun affecting global food production, with regions such as Australia, Europe, and Southern Africa experiencing major crop losses, while Asia, North America, and Central America face more diverse and region-specific challenges.

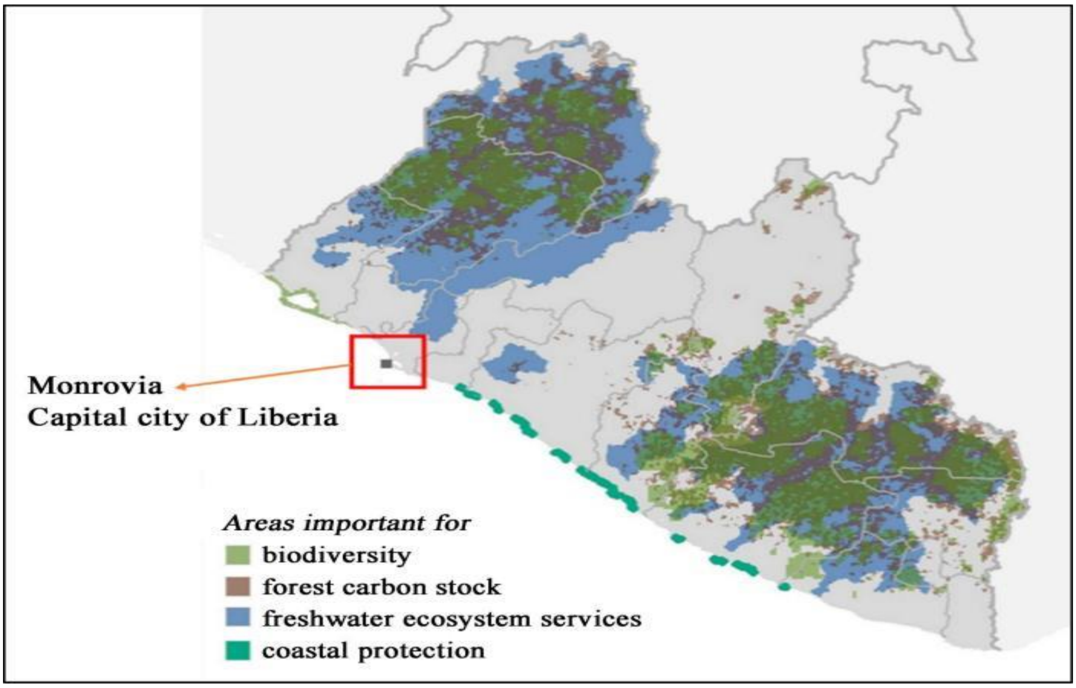
Greenhouse gas accumulation primarily carbon dioxide, methane, and nitrous oxides drives these changing climate patterns, reshaping ecosystems and threatening food systems globally. International efforts have focused on reducing carbon emissions, with agreements such as the Paris Climate Accord aiming to mitigate global warming (Surmaini and Runtunuwu, 2015; Perdinan et al., 2019). However, extreme weather events including floods, droughts, and temperature extremes continue to escalate, while shifting pest and disease dynamics pose significant risks to food production, particularly in tropical regions of West Africa (Asnawi, 2015; Campbell et al., 2016). These disruptions undermine local agricultural systems that depend on climate stability and are particularly vulnerable to unpredictable weather patterns (Hidayati and Suryanto, 2015).

Liberia, still recovering from nearly 14 years of civil conflict (1989-2003), faces compounded agricultural challenges. The conflict decimated agricultural infrastructure, displaced farming communities, and disrupted traditional farming practices (AfDB, 2016). Climate change poses an additional layer of risk, threatening fragile agricultural systems crucial for the livelihoods of approximately 70% of Liberia's population; agriculture contributes around 34% of the nation's GDP (Government of Liberia, 2019). The sector remains largely subsistence-based and heavily reliant on rainfall patterns, leaving smallholder farmers vulnerable to unpredictable climate variations.

Liberia's tropical climate and coastal geography make it particularly susceptible to climate change impacts. Rising sea levels threaten productive agricultural lands along the coast, while shifting rainfall patterns disrupt traditional planting and harvesting schedules. Similar to neighboring West African countries including Sierra Leone, Guinea, and Côte d'Ivoire, Liberia experiences increased temperature variability, altered rainy seasons, more frequent extreme weather events, and agricultural pest expansion into new regions (FAO, 2016). These changes pose significant risks to food security in a post-conflict nation striving to achieve stability and sustainable development.

Despite agriculture's critical importance to Liberia's economy and food security, research on climate change adaptation in the agricultural sector remains limited compared to other African nations such as Kenya, Ethiopia, and South Africa, where extensive climate-agriculture studies have been conducted (Lobell et al., 2008; Elum et al., 2017). This gap underscores the urgent need for systematic examination of climate change impacts and potential adaptation strategies in the Liberian context. Understanding how climate change affects Liberian agriculture and identifying appropriate adaptation strategies are essential for ensuring food security, reducing rural poverty, and supporting sustainable development. The vulnerability is particularly acute because most Liberian farmers are smallholders using traditional farming methods, with limited access to climate information, improved agricultural inputs, or adaptive technologies (Jayne et al., 2010).

By drawing on regional studies from West Africa and applying lessons from similar post-conflict and tropical contexts, this paper informs stakeholders about challenges and opportunities for maintaining agricultural productivity under changing climatic conditions. Identifying and promoting context-appropriate adaptation strategies is crucial for Liberia's agricultural resilience and long-term food security.



METHODOLOGY

This systematic literature review focuses on assessing agricultural productivity under climate change, with a specific emphasis on Sub-Saharan Africa, particularly contexts relevant to Liberia. The review synthesizes peer-reviewed articles and institutional reports that explore climate impacts on agriculture and adaptation strategies.

Search Strategy and Data Sources

The review utilized several electronic databases, including Google Scholar, ScienceDirect, Taylor and Francis

Online, Mendeley, Springer Link, and Wiley Online Library, with a publication date range from January 2011 to December 2024. Key search terms included "agriculture," "climate change," "food productivity," "adaptation strategies," "Liberia," "West Africa," "post-conflict agriculture," "smallholder farming," "tropical agriculture," and "climate resilience." Additionally, institutional reports from organizations like the **FAO**, **World Bank**, **USAID**, **UNDP**, **AfDB**, and **WFP** were incorporated to enrich the understanding of Liberia's agricultural challenges and climate vulnerability.

Inclusion Criteria

The following criteria were applied to select relevant studies:

1. Focus on tropical or West African agricultural systems.
2. Research on smallholder farming adaptation to climate change.
3. Climate projections specific to coastal West Africa.
4. Publications from 2011-2024 to capture recent trends.
5. Studies on major Liberian crops such as rice, cassava, maize, and vegetables.
6. Reports directly referencing Liberia or comparable West African contexts.

Exclusion Criteria

The review excluded:

1. Studies focused on temperate or arid regions.
2. Research on large-scale commercial agriculture not relevant to Liberia’s smallholder context.
3. Publications before 2011, unless they were seminal works.
4. Non-peer-reviewed studies or those lacking clear methodologies (except institutional reports).

Data Analysis and Synthesis

A total of 72 sources were analyzed, with key information extracted on:

1. Climate change impacts, including temperature shifts, rainfall variability, drought, flooding, and pest dynamics.
2. Effects on crop yields.
3. Adaptation strategies, their effectiveness, and challenges to implementation.
4. Applicability to Liberia’s post-conflict agricultural landscape.

The findings were synthesized thematically to identify:

1. Major climate change impacts on tropical agriculture.
2. Proven adaptation strategies from similar regions.
3. Context-appropriate recommendations for Liberia’s agricultural resilience.

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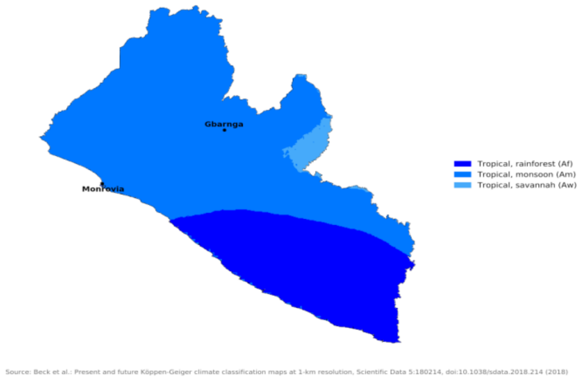
LIMITATIONS

The review primarily draws on regional studies, as there is a limited body of climate-agriculture research specific to Liberia. While the findings from comparable West African contexts are valuable, local factors such as soil types, microclimates, and socio-economic conditions may influence the applicability of these strategies. Further primary research in Liberia is needed to validate and refine these recommendations. This methodology provides a transparent, replicable framework for understanding the adaptation strategies relevant to Liberia's unique agricultural challenges.



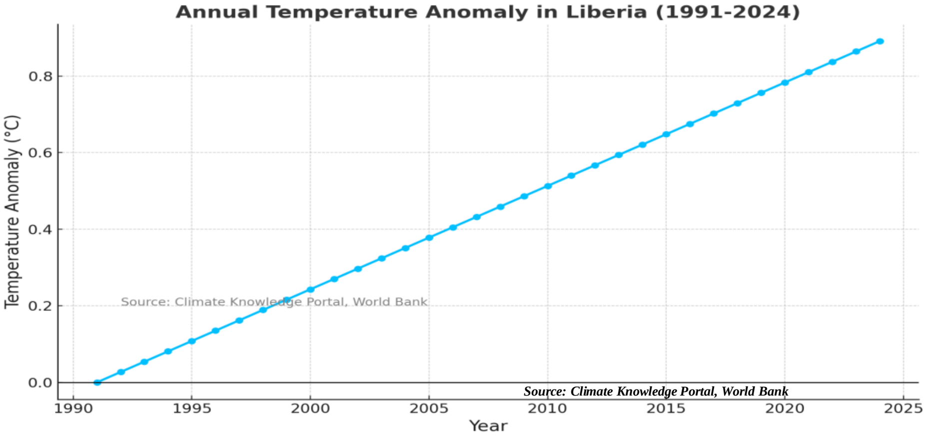
Climate Change Indicators for Liberia

Table 1: Climate Change Indicators and Projections for Liberia

Indicator	Current/Observed Trends	Future Projections	Agricultural Implications
Rainfall variability	Changes in onset; shortened rainy season; increased extreme rainfall events	More intense wet seasons; more pronounced dry spells through 2100	Unpredictable patterns challenge traditional planting calendars; increased flood and drought risk
Temperature increase	Average warming of ~0.27°C per decade (1991-2020)	Projected warming of ~2.6°C by the 2060s	Higher heat stress on crops and livestock; accelerated crop development; reduced yields
Sea-level rise / coastal inundation	~60% of Liberians live on or near coast; rising sea levels observed	Rise of 0.13-0.56 m by 2100 in coastal zones	Saltwater intrusion; loss of arable coastal lands; salinization of soils
Annual precipitation	2,391 mm (2022); historical mean ~2,467 mm (1991-2020)	High variability projected; overall totals may remain similar but distribution will change	Timing shifts more critical than total amounts; adaptation to variability essential

Sources: Climate Knowledge Portal (World Bank); LDC Climate Change Portal; UNFCCC National Communications; TheGlobalEconomy.com; ekmsliberia.info

Figure 1: Temperature and Precipitation Trends in Liberia (1991-2024)



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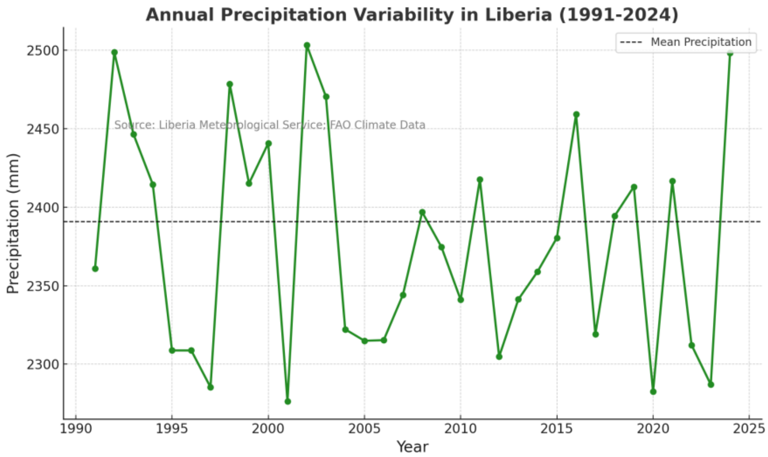

Source: Liberia Meteorological Service; FAO Climate Data

Climate Trends

Liberia remains one of the world's wettest countries with annual rainfall exceeding 2,300 mm. Yet, climate change introduces greater variability in rainfall patterns regarding onset, duration, and intensity, coupled with rising temperatures (Climate Knowledge Portal, 2024). The warming trend of approximately 0.27°C per decade may appear modest, but in tropical systems where species and crops have narrow thermal tolerances, even small temperature shifts significantly impact productivity (Heilmeier, 2019). For Liberian agriculture and ecosystems, changes in rainfall timing and intensity prove as consequential as changes in total precipitation. Delayed rainy seasons, heavy rainfall events followed by drought spells, and unpredictable wet-season onset create substantial challenges for rain-fed agriculture (FAO, 2016).

The large precipitation totals mask critical internal changes: more extreme rainfall events, increased flood risk, and accelerated soil erosion emerge as pressing concerns (Government of Liberia, 2020). Significant data gaps persist in year-by-year national values for climate metrics during 2020-2024 remain sparse, and local county-level climate change monitoring appears limited, highlighting the need for enhanced meteorological infrastructure and monitoring systems (UNDP, 2023).

Synthesis Of Climate Change Impacts on Liberian Agriculture

Temperature Effects on Crop Productivity

Temperature increases exceeding optimal thresholds for major crops represent a critical concern for Liberian agriculture. Research on tropical cereal crops indicates that temperature increases of 5°C could reduce maize yields by up to 40%, while rice yields could decrease by 40.2% with temperature rises of 1-3°C (Mall et al., 2017; Liu et al., 2020). For Liberia, where rice serves as the primary staple food, such productivity reductions pose serious food security threats.

According to the World Bank Climate Knowledge Portal (2024), Liberia's average temperatures have risen by approximately 0.27°C per decade between 1991 and 2020, with further increases of 2.6°C projected by the 2060s under current emission trajectories. While Liberia-specific crop response studies remain limited, regional research from similar West African tropical systems demonstrates comparable vulnerability (Campbell et al., 2016).

Elevated temperatures accelerate crop development phases such as seed-filling in cereals, shortening the grain growth period and producing smaller, less nutrient-dense seeds (Gray and Brady, 2016). Temperature stress during critical flowering periods, particularly in upland rice systems, can exacerbate yield losses by up to 50% (Lone et al., 2017). Cassava, though somewhat more heat-resilient than cereals, experiences reduced root bulking under prolonged high temperatures, diminishing yield potential (Henry, 2019). These temperature-related stresses represent significant threats to food security in Liberia, where many farmers rely on traditional, non-irrigated farming systems with limited adaptive capacity.

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Drought and Water Stress

Drought poses a persistent challenge for Liberia's predominantly rain-fed agricultural system. Climate change increases rainfall unpredictability, with extended dry periods and irregular rainy season onset and cessation (FAO, 2016). Water scarcity during critical crop growth stages limits agricultural productivity, particularly for rice, the nation's staple crop.

Studies conducted in neighboring West African countries with similar agricultural systems document that prolonged dry spells particularly affect upland rice systems dependent solely on rainfall (Masud et al., 2017). While systematic documentation of farmer experiences in Liberia remains limited, reports from extension services and development organizations working in the country indicate similar patterns (USAID, 2020; FAO Liberia, 2021).

Research demonstrates that drought conditions cause significant reductions in rice grain weight, affecting starch accumulation through reduced gene expression related to sucrose metabolism (Ruan et al., 2010). Cassava, generally considered drought-tolerant, also experiences yield reductions when prolonged dry conditions stunt root development (Espeland and Kettenring, 2018). Drought conditions exacerbate soil salinity, especially in coastal areas where saltwater intrusion damages crops and reduces soil fertility (Hopmans et al., 2021).

Rainfall Variability and Flooding

Rainfall variability constitutes another major climate change impact affecting Liberian agriculture. While some regions experience decreased total rainfall, others observe increases in rainfall intensity, creating heterogeneous impacts across the country (Climate Knowledge Portal, 2024). This variability reduces rainy season predictability, leading to crop losses and delayed planting decisions.

Agricultural assessments in Liberia's northern counties including Lofa, Nimba, and Bong document accelerated soil erosion from increasingly intense rainfall events (Government of Liberia MOA, 2019). Intense rainfall during critical crop development stages causes physical damage to plants, creates favorable conditions for pest proliferation, and complicates harvest operations (FAO, 2017).

Liberia experienced significant flooding events in recent years that inundated agricultural fields, damaged crops ready for harvest, and rendered land unsuitable for planting until floodwaters receded (World Bank, 2020; UNDP Liberia, 2021). While comprehensive national agricultural damage assessments from these specific events remain incomplete, local reports and humanitarian assessments document substantial crop losses, particularly in low-lying areas and river valleys.

Coastal areas, particularly in Montserrado and Grand Cape Mount counties, face increasing vulnerability to saltwater intrusion resulting from sea-level rise and higher tides (UNFCCC, 2018). Development reports and agricultural assessments document field abandonment in areas where salinization has rendered land unsuitable for cultivation, resulting in significant losses of productive agricultural land (AfDB, 2016; World Bank, 2019). Sea-level rise, combined with coastal erosion and more frequent storms, threatens Liberia's agricultural base, particularly in areas with limited land availability and lower infrastructure resilience.

Pest and Disease Dynamics

Temperature and humidity changes create favorable conditions for agricultural pest proliferation and range expansion. The fall armyworm (Spodoptera frugiperda), an invasive pest from the Americas, arrived in West Africa in 2016 and has since established itself as a persistent threat to maize and other cereal crops across the region, including Liberia (FAO, 2017; CABI, 2019). Similarly, cassava pests including mealybugs (Phenacoccus manihoti) and cassava mosaic disease spread through changing climatic conditions that favor their survival and reproduction (Legg et al., 2014).

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Climate change-induced high rainfall intensity, particularly affecting upland rice systems, leads to both waterlogging and subsequent drought stress, negatively affecting crop health and increasing vulnerability to pests and diseases (Pandey and Choudhary, 2019). Coastal areas witness damaging effects of saltwater intrusion, which weakens plant health and increases susceptibility to pests and diseases (Hopmans et al., 2021).

Adaptation Strategies for Liberian Agriculture

Based on the synthesis of regional evidence and documented successes in comparable contexts, the following adaptation strategies show promise for Liberian agriculture. While these strategies draw primarily from West African and tropical contexts, their effectiveness in Liberia requires validation through pilot programs and participatory research with local farmers.

Diversification of Crop Varieties and Species

Table 2: Crop Diversification Strategies Applicable to Liberia

Category	Crop Varieties/Species	Description	Regional Evidence
Drought-Tolerant Varieties	Rice (NERICA varieties), Cassava	NERICA rice varieties combine high yield potential with drought, disease, and pest tolerance; improved cassava varieties maintain productivity under water stress	AfRica Rice Center; IITA
Flood-Tolerant Varieties	Submergence-tolerant rice (STRASA program)	Rice varieties survive 1-2 weeks of complete submergence and recover after floodwaters recede	IRRI, AfRica Rice
Early-Maturing Varieties	Rice, Maize, Vegetables	Shorter life cycles allow harvest before drought or excessive rain causes damage	Multiple national programs
Heat-Tolerant Varieties	Rice, maize, vegetables	Maintain productivity at higher temperatures through improved breeding	CGIAR centers
Crop Diversification	Cassava, sweet potato, cowpea, groundnut, rice, maize	Diverse cropping systems spread risk; integrate drought-tolerant crops with traditional staples	Regional agricultural research

Sources: AfRica Rice Center (2020); International Institute of Tropical Agriculture (IITA, 2021); International Rice Research Institute (IRRI, 2019); FAO Crop Diversification Guidelines (2018)

Implementation Considerations for Liberia:

1. Access to improved seed remains limited; strengthening seed systems is critical
2. Farmer acceptance requires demonstration plots and field schools
3. Integration with traditional varieties can ease adoption
4. Partnership with regional research institutions (AfRica Rice, IITA) essential

Improved Water Management

Small-scale, farmer-managed irrigation systems using streams, springs, and shallow wells can provide supplementary water during dry spells. Technologies appropriate for Liberian conditions include treadle pumps, solar-powered motorized pumps, and gravity-fed irrigation systems (FAO, 2018).

Water Harvesting: Constructing ponds, small reservoirs, and catchment systems enables rainwater collection during wet periods for use during dry spells. At the household level, simple rainwater harvesting from roofs supports vegetable gardens during dry seasons (UNDP, 2020).

Soil Moisture Conservation: Practices reducing water evaporation include mulching with crop residues, minimum tillage preserving soil structure, and organic matter application improving water-holding capacity. These practices simultaneously conserve water and improve soil fertility (FAO, 2016).

Wetland Rice Intensification: Rehabilitating and expanding inland valley swamp rice cultivation makes better use of naturally available water and provides opportunities for controlled water management. These systems prove more resilient than upland rice during drought while supporting dry-season vegetable production (AfRica Rice, 2019).

Infrastructure Investment: Constructing small to medium-scale dams for irrigation and water supply, while ensuring proper drainage to prevent waterlogging, requires government prioritization in high agricultural potential areas (World Bank, 2019).

Adjustment of Planting Calendars

Table 3: Planting Calendar Adjustment Strategies

Strategy Category	Specific Actions	Description	Implementation Channel
Improved Climate Forecasting	Seasonal climate forecasts	Develop and disseminate forecasts 1-6 months ahead to guide planting decisions	Regional climate centers; national meteorological service
Flexible Planting Strategies	Guidance on actual rainfall onset	Provide updates on adjusting planting times based on observed conditions rather than traditional calendars	Extension services; farmer field schools
Multiple Planting Dates	Staggered planting	Spread risk by planting at multiple dates; if one planting fails, others may succeed	Farmer training programs
Early Warning Systems	Alerts for extreme weather	Develop SMS, radio, and community-based alerts for floods, droughts, and pest outbreaks	Mobile networks; community radio

Sources: West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL); AGRHYMET Regional Centre; FAO Climate-Smart Agriculture Guides

Agroforestry and Integrated Farming Systems

Table 4: Agroforestry Benefits and Systems for Liberia

Benefit Category	Mechanism	Description
Climate Moderation	Trees provide shade, windbreaks, root systems	Reduce temperature extremes, reduce moisture loss, improve water infiltration, reduce erosion
Diversified Income	Multiple products	Provide fruits, timber, fuelwood, fodder; reduce reliance on annual crops alone
Soil Improvement	Nitrogen-fixing species	Trees like Leucaena, Gliricidia, Acacia improve fertility through leaf litter and nitrogen fixation
Carbon Sequestration	Biomass and soil carbon	Sequester atmospheric carbon, contributing to climate mitigation
Resilience	System diversity	More resilient to climate shocks than monocultures

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Sources: World Agroforestry Centre (ICRAF, 2020); FAO Agroforestry Guidelines (2019); Trees for Food Security Project (2021)

Specific Agroforestry Systems for Liberia:

1. Improved fallow systems: Fast-growing, nitrogen-fixing trees during fallow periods enrich soil more rapidly than natural vegetation
2. Alley cropping: Annual crops grown between rows of periodically pruned trees/shrubs that provide mulch and nutrients
3. Home gardens: Intensive, multi-story cultivation around homesteads combining trees, vegetables, and small livestock
4. Cocoa and coffee under shade: Shade trees improve cocoa and coffee performance and resilience compared to full-sun cultivation

Conservation Agriculture

Table 5: Conservation Agriculture Principles and Practices

Principle	Practice	Benefits	Liberian Context
Reduced Tillage	Minimize plowing	Preserves soil structure, reduces erosion, maintains moisture, lowers labor	Particularly beneficial for farmers using hand tools
Soil Cover	Mulching, cover crops, crop residues	Protects from erosion, reduces evaporation, suppresses weeds, adds organic matter	Requires retention of residues (not burning)
Crop Rotation	Alternating crops	Breaks pest cycles, improves fertility (especially with legumes), spreads risk	Integration of legumes key
Organic Matter	Increase soil organic content	Enhances water-holding capacity, nutrient retention, biological activity	Compost, manure, green manures

Sources: FAO Conservation Agriculture (2020); African Conservation Tillage Network (ACT, 2021)

Implementation Requirements: Research and demonstration to show farmers the benefits and address concerns about initial yield reductions during transition to conservation agriculture. Farmer field schools and long-term support essential.

Integrated Pest Management (IPM)

Table 6: Integrated Pest Management Strategies

IPM Component	Specific Practices	Description
Crop Rotation and Diversity	Sequential and spatial crop variation	Disrupts pest life cycles and reduces pest buildup
Resistant Varieties	Genetically resistant crops	Provides built-in protection, reducing need for chemical control
Biological Control	Natural enemies, beneficial organisms	Promotes natural predators through habitat management
Cultural Practices	Planting date adjustment, field sanitation	Avoid peak pest periods; remove crop residues harboring pests
Judicious Pesticide Use	Proper selection, timing, safety	When necessary, train farmers in selection and

		safety
Monitoring and Early Warning	Pest surveillance systems	Community-based pest scouts; extension service alerts

Sources: FAO IPM Farmer Field Schools (2019); CABI Plantwise Program (2021)

Climate Information Services

Providing farmers with timely, relevant climate information enables informed decision-making and represents a critical adaptation strategy (WMO, 2020).

Key Components:

1. Seasonal forecasts: Disseminate rainfall, temperature, and dry spell forecasts 1-6 months ahead through radio, SMS, farmer groups, and extension services
2. Weather monitoring: Establish community-based weather stations; train local observers to record rainfall, temperature, and other parameters
3. Advisory services: Translate climate information into practical agricultural advice (when to plant, which varieties to use, water management strategies)
4. Indigenous knowledge integration: Combine traditional weather prediction methods with scientific forecasts to create trusted information systems

Soil Fertility Management

Maintaining and improving soil fertility is fundamental to climate resilience (FAO, 2021).

Key Practices:

1. Organic amendments: Promote compost, animal manure, and green manures to improve soil organic matter, water-holding capacity, and nutrient content
2. Integrated soil fertility management: Combine organic amendments with modest amounts of chemical fertilizers where accessible
3. Legume integration: Include legumes (cowpea, groundnut, soybean, green manures) in cropping systems to add nitrogen through biological fixation
4. Erosion control: Implement practices preventing soil loss on sloped lands (contour farming, terracing, grass strips, vegetation cover)
5. Site-specific management: Recognize that different soils and agroecological zones require different approaches; tailor guidance to local conditions rather than blanket recommendations

DISCUSSION

The adaptation strategies synthesized in this review derive primarily from experiences in comparable West African and tropical contexts rather than Liberia-specific empirical research. This limitation reflects the current state of climate-agriculture research in Liberia, where systematic studies remain scarce compared to countries like Ghana, Senegal, or Kenya that have more developed agricultural research infrastructure (Binswanger-Mkhize and Savastano, 2017).

Contextual Factors Affecting Implementation

Several factors influence the applicability and potential effectiveness of these strategies in Liberia:

Post-Conflict Recovery Context: Liberia's agricultural sector continues recovering from prolonged conflict, with weakened institutions, limited infrastructure, and disrupted knowledge transfer systems (AfDB, 2016). Adaptation strategies must account for these constraints and build on reconstruction efforts.

Smallholder Dominance: Most Liberian farmers operate small plots (typically <2 hectares) using hand tools and limited purchased inputs (Jayne et al., 2010). Adaptation strategies must be appropriate for resource-constrained smallholders rather than requiring significant capital investment.

Institutional Capacity: Extension services, research institutions, and input supply systems remain underdeveloped compared to regional peers (Government of Liberia MOA, 2019). Strengthening these systems must accompany technical adaptation strategies.

Gender Dimensions: Women perform significant agricultural labor in Liberia but face constraints in land access, credit, and decision-making authority (FAO, 2014). Gender-responsive adaptation approaches are essential.

Regional Variation: Liberia's diverse agroecological zones, coastal plains, inland valleys, and upland forests experience different climate impacts and require tailored strategies (CARI, 2015).

Evidence Gaps and Research Needs

This review identifies critical research needs for Liberia:

1. Localized Climate Projections: County-level climate projections and vulnerability assessments to guide targeted interventions
2. Crop Response Studies: Field trials assessing how major Liberian crops respond to temperature, drought, and flooding stress under local conditions
3. Adaptation Effectiveness: Participatory research evaluating which adaptation strategies work best for different farming systems, agroecological zones, and socioeconomic contexts
4. Farmer Knowledge and Practices: Documentation of indigenous adaptation strategies and farmer innovations
5. Economic Analysis: Cost-benefit analyses of adaptation interventions to guide investment priorities
6. Institutional Analysis: Assessment of extension service capacity, input supply systems, and policy frameworks affecting adaptation
7. Long-term Monitoring: Establishment of sentinel sites tracking climate trends, crop performance, and adaptation outcomes over time.

CONCLUSION

This systematic literature review synthesizes evidence on climate change impacts and adaptation strategies applicable to Liberia's agricultural sector. The synthesis draws on 72 peer-reviewed articles and institutional reports addressing tropical agriculture under climate change, with particular emphasis on West African contexts comparable to Liberia.

Climate change poses substantial challenges to Liberian agriculture through multiple pathways: rising temperatures (projected 2.6°C increase by 2060s), increasingly unpredictable rainfall despite high annual totals (>2,300 mm), more frequent droughts and floods, expanded pest and disease pressure, and sea-level rise threatening coastal agriculture (Climate Knowledge Portal, 2024; UNFCCC, 2018). These impacts overlay an agricultural sector still recovering from prolonged conflict, characterized by subsistence production, limited infrastructure, weak institutions, and vulnerable smallholder farmers (AfDB, 2016; Government of Liberia MOA, 2019).

However, the review identifies multiple adaptation strategies with demonstrated effectiveness in comparable contexts: crop diversification with improved varieties, enhanced water management, climate-informed planting calendars, agroforestry systems, conservation agriculture, integrated pest management, climate information services, and soil fertility management. These strategies, while drawing primarily from regional rather than Liberia-specific studies, offer evidence-based pathways for enhancing agricultural resilience.

Several crosscutting principles emerge from this synthesis:

1. **Farmer-Centered Approaches:** Climate adaptation must build on farmers' existing knowledge and priorities while providing new tools and information through participatory processes (Davis et al., 2012).
2. **Multi-Stakeholder Coordination:** Effective adaptation requires coordinated action across government agencies, farmers and their organizations, private sector actors, NGOs, and development partners, with clear roles and coordination mechanisms (Campbell et al., 2016).
3. **Equity and Inclusion:** Special attention must address vulnerable groups, particularly women and youth, ensuring they benefit from and participate meaningfully in adaptation efforts (FAO, 2014).
4. **Adaptive Management:** Adaptation constitutes an ongoing process of learning, adjusting, and innovating as climate continues changing and new challenges emerge, rather than a one-time intervention (Smith and Gregory, 2013).

Liberia's agricultural sector is central to its food security and economic development, but climate change poses a significant threat. With concerted effort from researchers, policymakers, development partners, and extension services, Liberia can enhance its agricultural resilience. The key to success lies in building climate resilience from the start of post-conflict reconstruction and prioritizing climate-smart agriculture, capacity building, and effective communication. By translating evidence-based strategies into action, Liberia can transform climate change from a challenge into an opportunity for agricultural innovation and sustainable development.

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