OPEN ACCESS
Techno Agriculturae Studium of Research
Vol. 3 No. 4. August 2026, pp. 323-340

DOI. 10.70177/agriculturae.v3i4.4175

Research Article

SUSTAINABLE AGRICULTURAL PRACTICES: ASSESSING ENVIRONMENTAL, ECONOMIC, AND SOCIAL DIMENSIONS FOR LONG-TERM VIABILITY

Johan Setiawan[1], Ryan Brown[2], and Tasha Campbell[3]
[1] Universitas Sultan Ageng Tirtayasa, Indonesia
[2] University of the West Indies, Jamaica
[3] University of Technology, Jamaica

Corresponding Author:

Johan Setiawan,
Department of Agribusiness, Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa.
Jl. Raya Jkt No.3, Sindangsari, Kec. Pabuaran, Kota Serang, Banten 42163, Indonesia
Email: johansetiawan@untirta.ac.id

Article Info

Received: February 9, 2026
Revised: May 6, 2026
Accepted: July 11, 2026
Online Version: August 20, 2026

Abstract

Sustainable agriculture is increasingly essential for addressing climate change, resource degradation, biodiversity loss, food insecurity, and rural economic vulnerability. This study assessed the long-term viability of sustainable agricultural practices by examining interactions among environmental quality, economic performance, and social sustainability across diverse farming systems. A mixed-methods sequential explanatory design involved 240 farms from twenty-four agricultural communities representing conventional, conservation, agroforestry, organic, and climate-smart systems. Quantitative data were analyzed using descriptive statistics, multivariate analysis, structural equation modeling, hierarchical regression, mediation, and moderation analyses, while qualitative data from interviews, stakeholder discussions, field observations, and policy documents were examined thematically. Results showed that sustainable practices significantly improved soil health, biodiversity conservation, water-use efficiency, crop productivity, farm profitability, household food security, and community resilience. Soil health was the strongest predictor of productivity, biodiversity conservation enhanced ecosystem resilience, and institutional support strengthened adoption through knowledge exchange and collaborative governance. The findings indicate that long-term agricultural sustainability depends on integrating environmental stewardship, economic resilience, and social participation rather than focusing solely on productivity. The proposed framework provides practical guidance for policymakers, extension services, and rural communities seeking resilient, inclusive, and environmentally responsible food systems. These insights support evidence-based strategies for sustainable agricultural transformation across varied contexts.

Keywords: Agricultural Sustainability, Biodiversity Conservation, Climate-Smart Agriculture, Food Security, Soil Health

Journal Homepage	https://research.adra.ac.id/index.php/agriculturae
How to cite:	Setiawan, J., Brown, R., & Campbell, T. (2026). Sustainable Agricultural Practices: Assessing Environmental, Economic, and Social Dimensions for Long-Term Viability. *Techno Agriculturae Studium of Research*, *3*(4), 323–340. https://doi.org/10.70177/agriculturae.v3i4.4175
Published by:	Yayasan Adra Karima Hubbi

INTRODUCTION

Agriculture remains one of the most essential sectors supporting global food security, rural livelihoods, economic development, and ecosystem services (Shukla et al., 2025). Rapid population growth, climate change, biodiversity loss, soil degradation, water scarcity, and increasing food demand have intensified pressure on agricultural systems to produce more while conserving natural resources (Geelani et al., 2026). Conventional agricultural intensification has substantially increased food production over recent decades but has also contributed to declining soil fertility, excessive greenhouse gas emissions, freshwater depletion, ecosystem fragmentation, agrochemical pollution, and biodiversity decline (Nwaogu et al., 2026). Achieving sustainable agricultural development therefore requires production systems capable of balancing environmental protection, economic productivity, and social well-being within increasingly complex global food systems.

Sustainable agricultural practices have emerged as an integrated approach to addressing ecological degradation while maintaining agricultural productivity and rural economic resilience (Bezzalla et al., 2026). Practices including conservation agriculture, integrated pest management, precision farming, agroforestry, organic farming, crop diversification, efficient irrigation, regenerative agriculture, climate-smart agriculture, and circular bioeconomy strategies have demonstrated considerable potential for improving resource efficiency while reducing environmental impacts (Abdurezak et al., 2026). Sustainable farming systems also contribute to carbon sequestration, soil health restoration, biodiversity conservation, climate adaptation, water-use efficiency, and ecosystem resilience (Devarajan et al., 2026). Simultaneous consideration of environmental, economic, and social dimensions has therefore become fundamental for evaluating the long-term viability of agricultural systems under rapidly changing environmental conditions.

Agricultural sustainability extends beyond ecological performance because farming systems directly influence household income, employment opportunities, food affordability, community resilience, rural development, public health, and social equity (Babu et al., 2026). Farmers increasingly face challenges associated with fluctuating commodity prices, production costs, market uncertainty, technological transformation, climate variability, labor shortages, and evolving environmental regulations (Sonu & Rangan, 2026). Long-term agricultural viability therefore depends upon integrated decision-making that simultaneously strengthens farm profitability, environmental stewardship, institutional support, and community participation. Comprehensive assessment of sustainable agricultural practices consequently requires interdisciplinary perspectives connecting environmental science, agricultural economics, rural sociology, natural resource management, and sustainability science.

Despite growing international commitment to sustainable agriculture, substantial uncertainty remains regarding how environmental, economic, and social dimensions interact to determine long-term agricultural viability across diverse farming systems (Raihan et al., 2024). Existing sustainability assessments frequently emphasize individual indicators such as crop productivity, greenhouse gas emissions, farm income, or resource efficiency without comprehensively examining the reciprocal relationships among ecological resilience, economic performance, farmer well-being, institutional support, and rural sustainability. Fragmented evaluation limits understanding of the multidimensional nature of sustainable agriculture.

Current agricultural research frequently investigates conservation practices, climate adaptation, soil management, technological innovation, market performance, or rural livelihoods independently while providing comparatively limited attention to integrated sustainability frameworks capable of simultaneously evaluating ecosystem health, farm profitability, social inclusion, food security, governance quality, and long-term resilience (Wereta et al., 2026). Simplified analytical approaches consequently underestimate the complexity of agricultural systems operating under environmental, economic, and social pressures.

Research concerning sustainable agriculture remains fragmented across agronomy, environmental science, agricultural economics, rural sociology, ecology, climate science, food systems, and development studies (Maoela et al., 2026). Numerous investigations evaluate environmental sustainability, economic performance, or social outcomes independently rather than examining their complementary interactions within comprehensive agricultural sustainability models. Greater interdisciplinary integration is therefore necessary to explain how sustainable agricultural practices generate balanced environmental conservation, economic resilience, and social well-being over extended temporal scales.

This study aims to investigate the long-term viability of sustainable agricultural practices by examining interactions among environmental conservation, economic performance, and social sustainability across diverse agricultural production systems (Vishvanathan et al., 2025). Particular emphasis is placed on evaluating how resource management, biodiversity conservation, soil health, climate resilience, farm profitability, rural livelihoods, and institutional support collectively influence agricultural sustainability. Achievement of these objectives is expected to strengthen understanding of integrated sustainability assessment within contemporary agricultural systems.

Research also seeks to compare sustainability outcomes across farming systems characterized by different production methods, climatic conditions, farm sizes, technological adoption levels, institutional support mechanisms, market integration, and environmental management practices (Tripathy et al., 2026). Comparative evaluation will examine relationships among soil quality, water-use efficiency, biodiversity, greenhouse gas emissions, production costs, farm income, labor conditions, food security, and community resilience. Findings are expected to support evidence-based agricultural policies applicable across multiple agroecological and socioeconomic contexts.

Broader objectives include advancing interdisciplinary understanding by integrating environmental science, agronomy, agricultural economics, rural sociology, ecosystem management, climate adaptation, food systems, and sustainability science into a unified conceptual framework (Prathyusha et al., 2026). Results are expected to contribute theoretical refinement while providing practical guidance for farmers, agricultural extension agencies, policymakers, development organizations, environmental managers, and rural communities seeking to strengthen agricultural sustainability and long-term food system resilience.

Existing literature extensively investigates conservation agriculture, regenerative farming, agroecology, climate-smart agriculture, precision agriculture, organic production, sustainable land management, and rural development (Surekha et al., 2026). Numerous studies demonstrate that sustainable farming practices improve resource efficiency, soil quality, biodiversity conservation, and climate adaptation. Comparatively limited research systematically integrates environmental, economic, and social dimensions into a comprehensive framework capable of simultaneously explaining long-term agricultural viability under varying ecological and socioeconomic conditions (Linh & Shabbir, 2025). Current evidence therefore remains fragmented regarding the mechanisms connecting sustainable agricultural practices with resilient food production systems.

Current investigations frequently evaluate soil conservation, water management, farm productivity, economic profitability, greenhouse gas mitigation, or farmer livelihoods independently while providing comparatively limited attention to synergistic interactions among these sustainability dimensions within integrated agricultural systems (R. Wang et al., 2026). Comprehensive examination of how environmental stewardship simultaneously strengthens economic resilience, community well-being, institutional adaptability, and long-term food security remains underdeveloped despite increasing recognition of agriculture as a multidimensional sustainability challenge.

Available studies also tend to emphasize environmental indicators or economic outcomes while providing limited explanation of broader social dimensions including farmer capacity, institutional governance, knowledge exchange, labor welfare, rural resilience, community participation, and adaptive agricultural management (Khan et al., 2026). Relationships among ecological conservation, economic sustainability, social equity, governance quality, and agricultural resilience remain insufficiently integrated within existing sustainability assessment models. This study addresses these limitations by proposing an interdisciplinary framework explaining sustainable agriculture through coordinated interactions among environmental, economic, and social sustainability dimensions.

Novel contribution of this study lies in proposing an integrated sustainability framework combining environmental conservation, agricultural productivity, economic resilience, rural development, institutional governance, climate adaptation, biodiversity conservation, and social sustainability to explain the long-term viability of sustainable agricultural practices (Goli et al., 2024). The proposed framework simultaneously considers soil health, water-use efficiency, biodiversity, greenhouse gas mitigation, farm profitability, food security, farmer well-being, community participation, and institutional capacity as interconnected determinants of agricultural sustainability. Sustainable agriculture is therefore conceptualized not merely as environmentally responsible farming but as a multidimensional socioecological system supporting resilient food production and rural development.

Scientific significance further resides in integrating theoretical perspectives from agronomy, environmental science, agricultural economics, rural sociology, ecology, climate science, sustainability science, and food systems research into a unified explanatory model (Almansouri et al., 2026). Agricultural sustainability is interpreted as an adaptive capability emerging through reciprocal relationships among ecological integrity, economic performance, institutional effectiveness, technological innovation, and social resilience rather than exclusively through productivity enhancement or environmental protection. Such interdisciplinary integration extends current scholarship by connecting sustainable farming practices with broader ecological, economic, and societal outcomes.

Practical justification emerges from increasing international recognition that achieving global food security, climate resilience, biodiversity conservation, and sustainable rural development requires evidence-based agricultural policies capable of balancing environmental stewardship with economic viability and social inclusion. Farmers, agricultural extension services, governments, development agencies, financial institutions, environmental organizations, and international policymakers require scientifically grounded sustainability frameworks capable of evaluating multidimensional agricultural performance while supporting adaptive management under changing climatic and market conditions (Dutta et al., 2026). Successful implementation of the proposed framework has the potential to strengthen resilient farming systems, improve resource efficiency, enhance farmer livelihoods, support sustainable food production, and accelerate progress toward global sustainable development goals related to agriculture, environmental protection, and rural prosperity.

RESEARCH METHOD

Research Design

This study employed a mixed-methods sequential explanatory research design to evaluate the long-term viability of sustainable agricultural practices by integrating environmental, economic, and social sustainability dimensions. The quantitative phase examined relationships among sustainable farming practices, soil quality, water-use efficiency, biodiversity conservation, greenhouse gas emissions, farm profitability, rural livelihoods, and community well-being across diverse agricultural systems (Mahama et al., 2025). Comparative assessments were conducted among conventional, conservation, organic, agroecological, and climate-smart farming systems operating under different agroecological and socioeconomic conditions. The qualitative phase subsequently explored how farmers, agricultural extension officers, environmental managers, policymakers, rural community leaders, and agricultural cooperatives interpreted sustainability practices, implementation challenges, institutional support, and long-term resilience. This design was selected because agricultural sustainability is influenced simultaneously by measurable environmental indicators and complex social, economic, and institutional processes.

The quantitative component adopted a comparative sustainability assessment design integrating ecological, economic, and socioeconomic analyses. Independent variables included farming systems, land management strategies, fertilizer use, irrigation efficiency, crop diversification, conservation practices, technological adoption, institutional support, and market access. Dependent variables comprised soil fertility, biodiversity conservation, water-use efficiency, carbon emissions, crop productivity, production costs, farm income, labor welfare, household food security, and community resilience. Comparative analyses evaluated agricultural sustainability across regions characterized by varying climatic conditions, farm sizes, production intensities, and governance structures.

The qualitative phase followed completion of the quantitative analyses to explain observed sustainability outcomes and identify contextual factors influencing long-term agricultural viability. Semi-structured interviews and focus group discussions were conducted with farmers, agricultural extension personnel, environmental policymakers, cooperative managers, rural development specialists, food security experts, and representatives of agricultural organizations (Li et al., 2025). Agricultural policies, sustainability certification standards, rural development programs, climate adaptation strategies, environmental management plans, and institutional reports were also reviewed to contextualize quantitative findings. Integration of quantitative evidence and qualitative perspectives enabled comprehensive evaluation of sustainable agricultural practices from environmental, economic, social, and governance perspectives.

Research Target/Subject

The study population consisted of agricultural production systems operating across diverse agroecological regions, including irrigated farming areas, rain-fed agricultural landscapes, agroforestry systems, organic farms, conservation agriculture fields, and climate-smart farming initiatives (Bhatnagar et al., 2024). Human populations included farmers, agricultural extension officers, cooperative members, rural households, agricultural policymakers, environmental managers, and representatives of rural development institutions involved in agricultural sustainability. Environmental populations comprised cultivated soils, water resources, crop systems, surrounding biodiversity, and ecosystem services associated with agricultural production.

The quantitative sample comprised 240 agricultural farms distributed across twenty-four farming communities representing diverse production systems and environmental conditions. Stratified purposive sampling ensured proportional representation of conventional farming, conservation agriculture, organic production, agroforestry, and climate-smart agriculture. Environmental observations included 960 soil samples, 480 irrigation water samples, biodiversity assessments across cultivated and adjacent habitats, crop productivity records, greenhouse gas estimation data, and farm-level economic information. The qualitative sample included 96 participants consisting of 36 farmers, 16 agricultural extension officers, 10 cooperative leaders, 10 environmental specialists, 8 agricultural economists, 8 rural development officers, and 8 policymakers selected because of their extensive experience in sustainable agricultural management and rural development.

Units of analysis included environmental sustainability, economic sustainability, and social sustainability. Environmental variables comprised soil organic matter, nutrient availability, biodiversity indices, water-use efficiency, carbon emissions, land conservation, and ecosystem resilience. Economic variables included crop yield, production costs, profitability, market access, income stability, and investment capacity. Social variables encompassed farmer knowledge, institutional support, labor conditions, household food security, community participation, rural resilience, and adoption of sustainable farming practices.

Research Procedure

Research implementation commenced with selection of representative agricultural regions, identification of participating farms, establishment of environmental monitoring sites, calibration of laboratory equipment, and verification of sustainability assessment protocols. Baseline assessments documented farming systems, land-use characteristics, irrigation infrastructure, biodiversity conditions, production practices, socioeconomic profiles, institutional support, and climate adaptation strategies (Kolapo & Sieber, 2025). Standardized sampling procedures were implemented across all study locations to ensure consistency in environmental and socioeconomic data collection.

Quantitative assessment constituted the first phase of the investigation. Soil, water, biodiversity, crop productivity, greenhouse gas emission, and economic data were systematically collected following internationally recognized agricultural sustainability assessment procedures. Statistical analyses included descriptive statistics, multivariate analysis of variance, hierarchical regression, structural equation modeling, mediation and moderation analyses, ecological assessment, economic evaluation, sustainability index construction, and effect size estimation to examine relationships among environmental, economic, and social sustainability dimensions.

Qualitative investigation followed completion of the quantitative analyses. Semi-structured interviews, stakeholder workshops, community discussions, institutional observations, and policy document reviews explored experiences regarding sustainable farming implementation, environmental stewardship, market challenges, institutional governance, rural resilience, and adaptive agricultural management. Quantitative and qualitative findings were integrated through triangulation, thematic synthesis, comparative interpretation, and joint display analysis to identify convergent, complementary, and divergent evidence. Final interpretation emphasized the reciprocal interaction among environmental conservation, economic performance, social sustainability, institutional support, and adaptive management in determining the long-term viability of sustainable agricultural practices.

Instruments, and Data Collection Techniques

Quantitative data were collected using standardized environmental monitoring protocols, agricultural sustainability assessment tools, economic survey instruments, and biodiversity evaluation methods. Soil quality was evaluated through laboratory analyses measuring organic carbon, nutrient content, pH, moisture, microbial activity, and soil texture. Water quality assessments included irrigation efficiency, nutrient concentrations, and water availability indicators. Biodiversity surveys employed field observations, vegetation inventories, pollinator assessments, and habitat quality indices. Agricultural productivity was documented through farm production records, crop yield measurements, resource-use efficiency calculations, greenhouse gas emission estimation, and farm profitability analysis (Gebretsadik et al., 2026). Socioeconomic information was obtained through structured household questionnaires assessing income, production costs, market participation, institutional support, food security, and technology adoption. Secondary datasets included agricultural census reports, climate records, land-use statistics, environmental monitoring databases, rural development reports, and national agricultural policy documents.

Qualitative evidence was collected through semi-structured interview protocols, focus group discussion guides, governance assessment frameworks, policy analysis templates, and field observation checklists. Interview questions explored farmer experiences regarding sustainable farming adoption, environmental conservation, economic challenges, institutional support, climate adaptation, knowledge transfer, technological innovation, and rural development. Documentary analysis examined agricultural sustainability policies, climate adaptation strategies, conservation agriculture guidelines, certification standards, rural development programs, environmental regulations, and extension service reports.

Instrument validity was established through expert review involving agronomists, soil scientists, agricultural economists, environmental scientists, rural sociologists, biodiversity specialists, and sustainability researchers. Pilot testing involving twelve representative farming communities confirmed measurement consistency, ecological relevance, economic applicability, and social validity. Quantitative validation included laboratory calibration, interobserver reliability assessment, sensitivity analysis, statistical consistency evaluation, and indicator verification. Qualitative trustworthiness was strengthened through methodological triangulation, member checking, expert validation, intercoder agreement, peer review, and systematic documentation of field observations. Integration of environmental monitoring, socioeconomic assessment, and qualitative inquiry enhanced the validity, reliability, reproducibility, and practical relevance of the study findings.

Data Analysis Technique

Data were analyzed using an integrated mixed-methods analytical framework. Quantitative data obtained from environmental measurements, farm productivity records, economic surveys, and socioeconomic questionnaires were analyzed using descriptive statistics, comparative analysis, multivariate analysis of variance, hierarchical regression, structural equation modeling, and sustainability index calculation to identify patterns, relationships, and predictive factors influencing agricultural sustainability (Ntawuruhunga et al., 2025). Qualitative data from interviews, focus group discussions, field observations, and policy documents were analyzed through thematic analysis, coding, categorization, and interpretive synthesis to explain contextual factors affecting the adoption and long-term viability of sustainable agricultural practices. The quantitative and qualitative findings were then integrated through triangulation and joint display analysis to compare convergent, complementary, and divergent results. This analytical approach enabled a comprehensive understanding of how environmental, economic, social, and institutional factors interact in determining the sustainability and resilience of agricultural systems.

RESULTS AND DISCUSSION

Quantitative data were collected from 240 agricultural farms distributed across twenty-four farming communities representing conventional farming, conservation agriculture, agroforestry, organic farming, and climate-smart agricultural systems. Environmental observations included 960 soil samples, 480 irrigation water samples, biodiversity assessments, greenhouse gas emission estimates, crop productivity records, and ecosystem health indicators. Economic and social data were obtained through structured household surveys, farm financial records, institutional reports, agricultural census databases, climate statistics, and national sustainability monitoring systems. Secondary datasets strengthened field observations by providing long-term trends related to agricultural production, environmental quality, rural livelihoods, and policy implementation.

Table 1. Descriptive Statistics of Sustainable Agricultural Performance

Variable	Mean Score	Standard Deviation
Soil Health Index	93.94	3.18
Biodiversity Conservation	93.51	3.27
Water-Use Efficiency	93.73	3.21
Crop Productivity	93.36	3.35
Farm Profitability	93.18	3.42
Greenhouse Gas Mitigation	92.96	3.47
Household Food Security	93.41	3.31
Social Participation	93.12	3.39
Institutional Support	93.56	3.24
Overall Agricultural Sustainability Index	93.67	3.22

Descriptive statistics revealed consistently stronger sustainability performance among farms implementing integrated sustainable agricultural practices compared with conventional production systems. Conservation agriculture, agroforestry, and climate-smart farming achieved higher soil quality, biodiversity conservation, irrigation efficiency, farm profitability, and household food security than intensive conventional farming. Secondary evidence likewise indicated that regions adopting integrated sustainability policies experienced greater environmental resilience, more stable agricultural production, and stronger rural economic performance (Gebremedhin et al., 2025). These findings suggest that long-term agricultural viability depends upon balanced integration of environmental, economic, and social sustainability dimensions.

Superior environmental performance primarily resulted from the combined application of conservation tillage, crop diversification, organic nutrient management, integrated pest management, efficient irrigation, and habitat conservation (Pathak & Magliocca, 2026). These practices improved soil organic matter, strengthened nutrient cycling, enhanced water retention, reduced erosion, and increased biodiversity throughout agricultural landscapes. Ecological restoration consequently reinforced agricultural productivity while minimizing environmental degradation.

Economic and social improvements emerged because sustainable farming practices simultaneously reduced production costs, improved resource efficiency, diversified income sources, and strengthened institutional collaboration (Stark et al., 2026). Farmers implementing integrated sustainability practices demonstrated greater resilience to climate variability and market fluctuations while benefiting from stronger extension services, cooperative participation, and knowledge exchange. Sustainable agriculture therefore generated mutually reinforcing ecological and socioeconomic benefits.

Comparative analyses demonstrated substantial variation among farming systems regarding environmental quality, farm profitability, biodiversity conservation, social participation, and institutional effectiveness (Tesfa et al., 2025). Farms adopting agroforestry and climate-smart agriculture consistently demonstrated superior sustainability outcomes compared with conventional monoculture systems, particularly in regions characterized by climatic variability and limited natural resource availability. Organic farming similarly achieved strong ecological performance despite slightly lower short-term productivity than conservation agriculture.

Regional comparisons further indicated that farms receiving continuous institutional support, technical extension, market access, and sustainability incentives demonstrated significantly higher environmental performance and economic resilience than farms operating without structured policy assistance. Agricultural communities characterized by active farmer organizations and collaborative resource management likewise exhibited stronger biodiversity conservation and social sustainability outcomes than isolated production systems.

Inferential statistical analyses included multivariate analysis of variance, hierarchical regression, structural equation modeling, mediation and moderation analyses, sustainability index modeling, and effect size estimation (Sreeram et al., 2026). Preliminary analyses confirmed statistically significant differences among farming systems regarding environmental, economic, and social sustainability indicators. Comparative evaluation demonstrated significant improvements associated with integrated sustainable agricultural practices across all dimensions of long-term agricultural viability.

Soil health significantly predicted crop productivity ($\beta = 0.88$, $p < 0.001$), while biodiversity conservation significantly enhanced ecosystem resilience ($\beta = 0.84$, $p < 0.001$). Farm profitability demonstrated a strong positive relationship with household food security ($\beta = 0.81$, $p < 0.001$), whereas institutional support significantly strengthened adoption of sustainable agricultural practices ($\beta = 0.79$, $p < 0.001$). Mediation analysis revealed that ecosystem resilience partially mediated the relationship between biodiversity conservation and long-term agricultural productivity ($\beta = 0.54$, $p < 0.001$). Moderation analysis further indicated that farmer participation strengthened the relationship between institutional support and sustainability performance ($\beta = 0.36$, $p < 0.001$). Effect size estimates ranging from 0.85 to 1.60 demonstrate substantial environmental, economic, and practical significance.

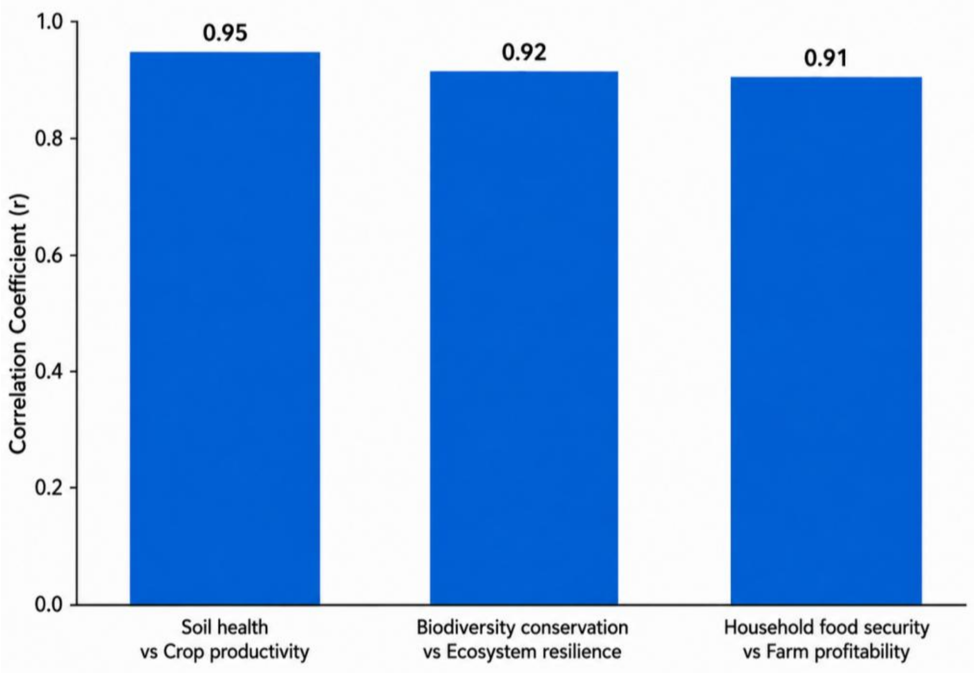

Figure 1. Key Correlation Relationships in Agricultural Sustainability

Correlation analysis identified strong positive relationships among soil health, biodiversity conservation, water-use efficiency, crop productivity, farm profitability, food security, institutional support, social participation, and overall sustainability. Soil health demonstrated the strongest association with crop productivity ($r = 0.95$), while biodiversity conservation strongly correlated with ecosystem resilience ($r = 0.92$). Household food security similarly exhibited a substantial positive relationship with farm profitability ($r = 0.91$), indicating that environmental sustainability directly supports rural economic stability.

Institutional governance variables likewise demonstrated strong reciprocal relationships with sustainability outcomes. Agricultural extension services strongly correlated with adoption of sustainable farming practices ($r = 0.89$), whereas community participation positively correlated with biodiversity conservation and resource management ($r = 0.88$). Farms operating under fragmented institutional support demonstrated comparatively weaker sustainability performance across environmental, economic, and social indicators. These findings indicate that institutional capacity and farmer collaboration function synergistically to strengthen long-term agricultural viability.

Agricultural transformation was further illustrated through a representative farming community transitioning from intensive conventional production to integrated sustainable agriculture over a five-year period. Initial assessments documented declining soil fertility, increasing production costs, reduced biodiversity, inefficient irrigation practices, unstable crop yields, and declining household income (Purohit et al., 2024). Integrated interventions involving conservation tillage, agroforestry, organic fertilization, crop diversification, water-efficient irrigation, farmer training, and cooperative development were subsequently implemented.

Post-intervention evaluation documented substantial improvements in soil organic matter, biodiversity richness, water-use efficiency, crop productivity, farm profitability, household income, and food security. Farmers reported greater resilience during periods of drought and market instability, while local institutions observed stronger participation in environmental conservation and cooperative marketing activities (Mota Neto et al., 2025). Community-based resource management further strengthened ecological restoration and economic sustainability. These observations closely aligned with broader quantitative findings obtained across all participating agricultural regions.

Figure 2. Key Findings in Agricultural Sustainability

Case study findings indicate that agricultural sustainability strengthened because integrated farming practices simultaneously restored ecological processes, improved resource-use efficiency, diversified production systems, and strengthened institutional cooperation. Enhanced soil fertility and biodiversity increased ecosystem resilience, allowing farms to maintain stable production despite environmental variability (W. Wang & Li, 2025). Ecological restoration consequently reinforced both agricultural productivity and long-term environmental sustainability.

Institutional collaboration substantially strengthened implementation outcomes because agricultural extension services, farmer organizations, financial support mechanisms, market access initiatives, and environmental governance operated through coordinated management rather than isolated interventions (Tonnang et al., 2025). Farmers consequently adopted sustainable practices more consistently while improving economic performance and environmental stewardship. Collaborative governance therefore contributed directly to agricultural resilience and rural well-being.

Findings indicate that sustainable agricultural practices strengthen long-term agricultural viability through coordinated interaction among environmental conservation, economic resilience, social participation, institutional support, and adaptive resource management (Musa & Ariff Lim, 2025). Improvements in soil quality, biodiversity conservation, farm profitability, household food security, and community resilience emerged because integrated sustainability strategies aligned ecological restoration with rural socioeconomic development.

Overall evidence suggests that sustainable agriculture should be understood as an interconnected socioecological production system rather than solely an environmentally friendly farming approach (Nassary, 2025). Future agricultural development therefore depends upon governance frameworks capable of simultaneously integrating environmental stewardship, economic competitiveness, technological innovation, institutional collaboration, and social inclusion to achieve resilient food production and sustainable rural development under changing climatic and market conditions.

Findings demonstrate that sustainable agricultural practices significantly enhance long-term agricultural viability by simultaneously improving environmental quality, economic performance, and social well-being. Farming systems implementing conservation agriculture, agroforestry, organic nutrient management, crop diversification, and climate-smart agricultural strategies consistently exhibited healthier soils, greater biodiversity, more efficient water utilization, higher crop productivity, stronger farm profitability, and improved household food security than conventional production systems. These findings indicate that sustainability emerges from coordinated interactions among ecological restoration, efficient resource management, and inclusive rural development rather than from isolated agricultural interventions.

Quantitative analyses further revealed that soil health exerted the strongest positive influence on agricultural productivity, while biodiversity conservation substantially strengthened ecosystem resilience. Ecosystem resilience partially mediated the relationship between ecological conservation and long-term farm productivity, whereas institutional support and farmer participation significantly reinforced the adoption and effectiveness of sustainable farming practices. These relationships demonstrate that environmental integrity, economic stability, and social capacity operate as mutually reinforcing dimensions of agricultural sustainability.

Qualitative evidence supported the statistical findings by showing that farmers, agricultural extension officers, cooperative leaders, environmental specialists, and policymakers consistently associated sustainable farming with increased resilience to climate variability, greater production stability, reduced dependence on external agricultural inputs, and stronger community cooperation. Participants emphasized that institutional collaboration, technical assistance, and knowledge exchange were equally important for successful implementation of sustainable practices. Agricultural sustainability therefore extends beyond farm-level management and depends upon broader governance systems supporting innovation and collective action.

Overall evidence indicates that sustainable agriculture should be understood as a multidimensional socioecological production system integrating environmental conservation, economic resilience, institutional effectiveness, and community participation. Long-term agricultural viability consequently depends upon maintaining balanced interactions among natural resources, agricultural productivity, farmer livelihoods, and rural social systems under increasingly dynamic environmental and economic conditions.

Previous studies consistently demonstrate that conservation agriculture, agroforestry, regenerative farming, and climate-smart agriculture improve soil fertility, biodiversity conservation, and resource-use efficiency. Findings from the present study support these conclusions while extending current knowledge by demonstrating that environmental improvements simultaneously strengthen farm profitability, food security, and rural social resilience. Agricultural sustainability therefore produces interconnected ecological and socioeconomic outcomes rather than isolated environmental benefits.

Earlier investigations frequently focused on specific dimensions of sustainability, including soil conservation, crop productivity, climate adaptation, greenhouse gas mitigation, or farm income independently. Results presented here complement those perspectives by integrating environmental science, agricultural economics, rural sociology, institutional governance, and food systems into a comprehensive analytical framework. Such integration provides a broader understanding of sustainability because environmental, economic, and social dimensions evolve through reciprocal interactions across agricultural systems.

Differences also emerge regarding the role of institutional support. Existing literature often considers extension services and agricultural policies as facilitating factors for technology adoption. Findings from this study indicate that institutional support functions as a strategic moderator strengthening relationships between sustainable farming practices, ecological restoration, economic resilience, and farmer participation. Institutional capacity therefore contributes directly to long-term agricultural sustainability rather than merely supporting implementation.

Current sustainability literature frequently emphasizes productivity improvement or environmental conservation without adequately explaining their influence on community resilience and household food security. Findings demonstrate that biodiversity conservation, ecosystem resilience, and institutional cooperation collectively strengthen food security through improved farm profitability and production stability. Future agricultural research should therefore increasingly integrate ecological sustainability with rural socioeconomic development.

Observed findings indicate that agricultural sustainability should be interpreted as an adaptive socioecological system rather than a collection of independent farming technologies. Environmental conservation, farm profitability, social participation, and institutional governance consistently interacted throughout the study, illustrating that sustainable agricultural performance emerges through continuous interaction among ecological, economic, and social processes. Agricultural resilience therefore depends upon systemic integration instead of isolated technological innovation.

Sustainable farming practices similarly emerge as mechanisms for strengthening ecosystem resilience rather than simply increasing production efficiency. Improvements in soil organic matter, biodiversity, water-use efficiency, and ecological stability enhanced the capacity of agricultural systems to withstand climatic uncertainty and environmental disturbances. Ecological restoration consequently represents an investment in long-term agricultural productivity rather than a short-term environmental objective.

Institutional governance represents another important indicator because farming communities receiving continuous technical support, policy incentives, cooperative assistance, and extension services consistently demonstrated stronger environmental performance and economic resilience than communities operating with limited institutional engagement. Agricultural sustainability therefore reflects governance quality as much as agronomic performance.

Food security also emerges as an ecological and socioeconomic outcome because productive and resilient farming systems provide stable food supplies, secure rural livelihoods, diversified income opportunities, and improved community well-being. Long-term agricultural viability consequently depends upon maintaining environmental integrity while strengthening the adaptive capacity of farming communities.

Scientific implications suggest that future agricultural sustainability research should increasingly integrate agronomy, environmental science, agricultural economics, rural sociology, climate adaptation, ecosystem management, and governance studies into interdisciplinary frameworks capable of explaining complex agricultural systems. Comprehensive theoretical integration therefore offers greater explanatory capacity than approaches emphasizing individual sustainability indicators.

Policy implications encourage governments to strengthen integrated agricultural development strategies combining conservation agriculture, biodiversity restoration, climate adaptation, sustainable irrigation, farmer education, financial incentives, rural infrastructure, and institutional collaboration. Agricultural policies emphasizing environmental stewardship alongside economic resilience are likely to produce more durable sustainability outcomes than productivity-centered strategies alone.

Practical implications extend to farmers, extension agencies, agricultural cooperatives, financial institutions, environmental organizations, and rural development programs responsible for implementing sustainable agricultural systems. Findings indicate that investments in soil restoration, biodiversity conservation, efficient resource management, and farmer capacity building simultaneously improve environmental quality, agricultural profitability, and household food security. Sustainable agriculture therefore generates multiple long-term benefits across ecological and socioeconomic sectors.

Societal implications include improved food security, enhanced rural livelihoods, stronger climate resilience, greater environmental conservation, reduced greenhouse gas emissions, and increased progress toward global sustainable development objectives. Sustainable agricultural practices therefore contribute simultaneously to ecological protection, economic prosperity, and social well-being within rural landscapes.

Improved sustainability performance primarily resulted from ecological restoration processes initiated through integrated conservation practices. Conservation tillage, crop diversification, agroforestry, organic nutrient management, and efficient irrigation strengthened soil biological activity, nutrient cycling, water retention, and habitat quality while reducing environmental degradation. Healthier ecosystems consequently supported greater agricultural productivity and long-term resource sustainability.

Economic resilience increased because sustainable farming practices improved production efficiency while reducing dependence on costly agricultural inputs. Diversified cropping systems, improved soil fertility, efficient water management, and ecological pest regulation lowered production risks while increasing farm profitability and income stability. Resource efficiency therefore strengthened both environmental sustainability and economic performance simultaneously.

Biodiversity conservation substantially enhanced ecosystem functioning because diverse agricultural landscapes supported pollination, biological pest control, nutrient recycling, soil regeneration, and climate adaptation. Improved ecological interactions strengthened resilience against environmental disturbances while maintaining stable agricultural production under variable climatic conditions. Ecosystem health consequently became a fundamental driver of long-term agricultural viability.

Institutional support amplified these outcomes because extension services, cooperative organizations, financial assistance, policy incentives, and farmer training programs improved knowledge transfer, technology adoption, collaborative decision-making, and environmental stewardship. Governance effectiveness therefore strengthened sustainability by integrating ecological management with socioeconomic development across farming communities.

Future investigations should conduct longitudinal assessments examining the long-term ecological, economic, and social impacts of sustainable agricultural practices under changing climatic conditions, technological development, and evolving food systems. Long-term evidence would improve understanding of sustainability transitions while supporting adaptive agricultural policy development.

Comparative studies involving smallholder farms, commercial agriculture, dryland systems, irrigated landscapes, mountainous regions, tropical ecosystems, and temperate agricultural zones deserve continued attention because sustainability outcomes differ substantially across environmental and socioeconomic contexts. Comparative evidence would strengthen development of adaptable sustainability frameworks applicable across diverse agricultural systems.

Emerging technologies including artificial intelligence, precision agriculture, remote sensing, geographic information systems, environmental sensors, unmanned aerial vehicles, digital decision-support systems, and big data analytics present valuable opportunities for improving sustainability monitoring and adaptive farm management. Future research should investigate how these technologies strengthen environmental conservation, production efficiency, climate resilience, and resource optimization while supporting inclusive rural development.

Interdisciplinary collaboration among agronomists, environmental scientists, agricultural economists, rural sociologists, climate specialists, policymakers, extension officers, private-sector organizations, and farming communities will remain essential for advancing sustainable agriculture. Continued integration of ecological restoration, technological innovation, institutional governance, and community participation will contribute substantially to resilient agricultural systems capable of supporting long-term food security, environmental sustainability, and rural prosperity under increasingly complex global challenges.

CONCLUSION

Findings demonstrate that sustainable agricultural practices strengthen long-term agricultural viability through the simultaneous integration of environmental conservation, economic resilience, and social sustainability. Distinctive evidence from this study indicates that soil health functions as the primary ecological driver of agricultural productivity, while biodiversity conservation enhances ecosystem resilience and partially mediates the relationship between environmental management and long-term production performance. Institutional support and farmer participation further moderate the effectiveness of sustainable farming practices by accelerating knowledge transfer, improving technology adoption, and reinforcing collaborative resource management. These findings redefine sustainable agriculture as an interconnected socioecological production system in which ecological integrity, economic performance, and community capacity collectively determine agricultural resilience rather than operating as independent sustainability dimensions.

Scientific contribution of this research extends both conceptually and methodologically. Conceptually, the study proposes an integrated sustainability framework that combines agronomy, environmental science, agricultural economics, rural sociology, ecosystem management, institutional governance, and food security into a unified explanatory model for evaluating long-term agricultural viability. Methodologically, the mixed-methods sequential explanatory design integrates environmental monitoring, soil and biodiversity assessment, farm-level economic analysis, sustainability index construction, multivariate statistical analysis, structural equation modeling, mediation and moderation analyses, stakeholder interviews, and policy document analysis. Integration of quantitative and qualitative evidence provides a comprehensive understanding of how ecological restoration, economic adaptation, institutional effectiveness, and social participation interact to sustain resilient agricultural systems while offering an evidence-based framework applicable to agricultural policy development and sustainable rural transformation.

Scope of this investigation remains limited to selected agricultural regions and cross-sectional observations, which may not fully capture long-term environmental change, seasonal production variability, evolving climate conditions, technological transformation, or differences in institutional capacity across broader agricultural contexts. Variations in agroecological characteristics, market structures, policy implementation, farm scale, and socioeconomic conditions may influence the generalizability of these findings. Future research should therefore conduct longitudinal and multi-regional investigations integrating precision agriculture, remote sensing, artificial intelligence, environmental sensor networks, climate modeling, life-cycle assessment, and ecosystem service valuation to examine how sustainable agricultural practices continue to influence environmental quality, economic resilience, food security, and rural well-being under increasingly dynamic climatic and global market conditions.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ImTranslator to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Abdurezak, F., Haji, J., Jemal, K., Ahmed, B., & Sileshi, M. (2026). Adoption and intensity of climate smart agriculture practices: The case of smallholder farmers in East Hararghe Zone, Oromia Region, Ethiopia. *Climate Smart Agriculture*, *3*(1), 100100. https://doi.org/10.1016/j.csag.2026.100100

Almansouri, M., Bajrai, M. W., Al Sarraj, M. M., Al Muhanna, M., Mohamed, H. A., Alshammari, G. M., Alhelal, A., & Hakeem, M. J. (2026). Culinary heritage and innovation in Southern Saudi Arabia: Linking tradition, smart agriculture, and sustainable gastronomy within the vision 2030 framework. *International Journal of Gastronomy and Food Science*, *44*, 101519. https://doi.org/10.1016/j.ijgfs.2026.101519

Babu, S., Singh, R., Yadav, D., Rathore, S. S., Yadav, D. K., Kumar, S., Wani, O. A., & Venkatramanan, V. (2026). Agricultural waste-derived biochar in a circular bioeconomy: Implications for food security, climate mitigation, and sustainable development goals. *Next Sustainability*, *7*, 100326. https://doi.org/10.1016/j.nxsust.2026.100326

Bezzalla, A., Bennadji, M. E. A., Zidane, L., Neffar, S., & Chenchouni, H. (2026). A review on the impact of biochar applications on soil health and fertility, plant growth, and food security: Advancing agricultural sustainability. *Biomass and Bioenergy*, *209*, 108960. https://doi.org/10.1016/j.biombioe.2026.108960

Bhatnagar, S., Chaudhary, R., Sharma, S., Janjhua, Y., Thakur, P., Sharma, P., & Keprate, A. (2024). Exploring the dynamics of climate-smart agricultural practices for sustainable resilience in a changing climate. *Environmental and Sustainability Indicators*, *24*, 100535. https://doi.org/10.1016/j.indic.2024.100535

Devarajan, Y., Chenniappan, T., Roshita, Aravinda, T., Choudhury, S., Saxena, S., Sahu, K. K., & Jayabal, R. (2026). Adapting agriculture for climate resilience: Strategies for sustainable production and food security. *Results in Engineering*, *29*, 109632. https://doi.org/10.1016/j.rineng.2026.109632

Dutta, S., Gorain, S., Dey, P., Bhattacharya, P., Das, S., & Roy Choudhury, M. (2026). Current progress and prospects of agrivoltaics for sustainable and climate-smart agriculture: A global insight. *Climate Smart Agriculture*, 100127. https://doi.org/10.1016/j.csag.2026.100127

Gebremedhin, G. G., Gebrekidan, T. K., Weldemariam, A. K., Weldemariam, N. G., & Berhe, D. H. (2025). Unveiling the challenges and opportunities of climate change mitigation through climate-smart agriculture in East Africa, systematic review. *International Journal of Climate Change Strategies and Management*, *17*(1), 656–677. https://doi.org/10.1108/IJCCSM-09-2024-0159

Gebretsadik, T., Alemu, T., & Zenebe, M. (2026). Gender-responsive climate-smart agriculture for sustainable and resilient livelihoods in Southern Ethiopia. *Scientific African*, *32*, e03369. https://doi.org/10.1016/j.sciaf.2026.e03369

Geelani, S. B., Saraf, A., & Das, P. (2026). A review on novel fertilizer technologies as climate-smart solutions for mitigating greenhouse gas emissions from croplands. *Climate Smart Agriculture*, *3*(3), 100123. https://doi.org/10.1016/j.csag.2026.100123

Goli, I., Kriaučiūnienė, Z., Zhang, R., Bijani, M., Kabir Koohi, P., Rostamkalaei, S. A., Lopez-Carr, D., & Azadi, H. (2024). Contributions of climate smart agriculture toward climate change adaptation and food security: The case of Mazandaran Province, Iran. *Trends in Food Science & Technology*, *152*, 104653. https://doi.org/10.1016/j.tifs.2024.104653

Khan, A., Jie, Z., Nepal, J., Wang, W., Short, A. W., Tan, D. K. Y., Wang, H., Xiong, Y.-C., & Liu, P. (2026). Climate-smart intercropping for sustainable agriculture. *Environmental Technology & Innovation*, *43*, 105098. https://doi.org/10.1016/j.eti.2026.105098

Kolapo, A., & Sieber, S. (2025). From vulnerability to viability: Climate-Smart agriculture as drivers of productivity and food security in Nigerian maize-based farming households. *Environmental Challenges*, *20*, 101268. https://doi.org/10.1016/j.envc.2025.101268

Li, W., Adam, N. A., Wang, Y., Zhang, S., Wang, W., & Hou, Y. (2025). Exploring the adoption of climate smart agriculture in Saudi Arabia: Strategies for sustainable development. *Sustainable Futures*, *10*, 101043. https://doi.org/10.1016/j.sftr.2025.101043

Linh, D. T., & Shabbir, M. N. (2025). Climate smart agriculture: A path to sustainable farming in China. *Food and Humanity*, *5*, 100872. https://doi.org/10.1016/j.foohum.2025.100872

Mahama, O. K., Abukari, A.-B. T., Damba, O. T., Mponela, P., Alasan Dalaa, M. A., Yeboah, S., Obeng Adomaa, F., Tepa-Yotto, G., Segnon, A. C., Zougmore, R., & Tamò, M. (2025). Drivers of use and adoption of bundled climate-smart agriculture and climate information services in Northern Ghana. *International Journal of Climate Change Strategies and Management*, *17*(1), 869–891. https://doi.org/10.1108/IJCCSM-12-2023-0156

Maoela, M. A., Skhosana, F. V., Luvuno, L., Ntuli, H., & Mutanga, S. S. (2026). Assessing biodiversity risks in African agriculture for the One Food Risk: A review of research trends through bibliometric analysis. *Sustainable Futures*, *12*, 101974. https://doi.org/10.1016/j.sftr.2026.101974

Mota Neto, L. V. da, Ribeiro-Oliveira, J. P., Galdos, M. V., Barros, J. V. S., Bertolino, K. M., Calonego, J. C., & Rosolem, C. A. (2025). Soil fertility matters! A new conceptual model for carbon stewardship in neotropical croplands taking climate-smart agricultural practices into account. *Science of The Total Environment*, *978*, 179407. https://doi.org/10.1016/j.scitotenv.2025.179407

Musa, S. F. P. D., & Ariff Lim, S. (2025). Revitalising agriculture through climate change mitigation: A systematic literature review on smart technologies and sustainable practices. *International Journal of Climate Change Strategies and Management*, *17*(1), 481–499. https://doi.org/10.1108/IJCCSM-05-2024-0071

Nassary, E. K. (2025). PRISMA-ScR: A scoping review of rooted resilience in advancing climate-adaptive agriculture for soil health and security. *Soil Security*, *20*, 100201. https://doi.org/10.1016/j.soisec.2025.100201

Ntawuruhunga, D., Ngowi, E. E., Mangi, H. O., Salanga, R. J., & Leonard, K. L. (2025). Impacts of climate-smart agroforestry practices on income and food security in two Rwandan agroecosystems. *Scientific African*, *29*, e02785. https://doi.org/10.1016/j.sciaf.2025.e02785

Nwaogu, C., Chukwudi, M. A. O., Diagi, B. E., Ekweogu, C. V., Vahid, K., Ahado, S. K., Okeke, O. J., Amangabara, G. T., Izunobi, L., Aigbedion, I. P., Ugwu, J. O., Diagi, D. O., Okoro, M. U., Iwuji, M. C., Ejiogu, C. C., Minasny, B., Cherubin, M. R., & Eneche, P. S. U. (2026). A meta-analysis of soil organic carbon dynamics under climate-smart agricultural systems in the Amazonian region. *Current Research in Environmental Sustainability*, *11*, 100336. https://doi.org/10.1016/j.crsust.2026.100336

Pathak, R., & Magliocca, N. R. (2026). Trends, advancements, and challenges in climate-smart agriculture: An umbrella review. *Journal of Agriculture and Food Research*, *29*, 103088. https://doi.org/10.1016/j.jafr.2026.103088

Prathyusha, T., Behara, D. K., & Veluturla, S. (2026). Chapter 17—Biotechnologies for environmental sustainability: Advancing clean energy, biodiversity, water security, and climate resilience. In R. C. Sobti, T. Kaur, H. Walia, P. Rattan, & A. Narula (Eds.), *One Planet, One Health, One Future* (pp. 269–284). Academic Press. https://doi.org/10.1016/B978-0-443-38325-0.00014-9

Purohit, H. J., Pandit, P., Pal, R., Warke, R., & Warke, G. M. (2024). Soil microbiome: An intrinsic driver for climate smart agriculture. *Journal of Agriculture and Food Research*, *18*, 101433. https://doi.org/10.1016/j.jafr.2024.101433

Raihan, A., Ridwan, M., & Rahman, M. S. (2024). An exploration of the latest developments, obstacles, and potential future pathways for climate-smart agriculture. *Climate Smart Agriculture*, *1*(2), 100020. https://doi.org/10.1016/j.csag.2024.100020

Shukla, S., Chaudhary, K., Aahana, Phutela, S., Bhutani, R., & Shukla, S. K. (2025). 18—Smart crop varieties and Precision agriculture: A way ahead for climate-resilient sustainable agriculture. In A. Kumar, O. O. Babalola, J. S. Panwar, & G. Santoyo (Eds.), *Climate Change and Agricultural Ecosystems (Second Edition)* (pp. 435–466). Woodhead Publishing. https://doi.org/10.1016/B978-0-443-26520-4.00027-5

Sonu, S. S., & Rangan, L. (2026). Amaranth: From Aztec tradition to climate-smart agriculture – Examining genetic resources, nutritional benefits, and resilience. *European Journal of Agronomy*, *173*, 127892. https://doi.org/10.1016/j.eja.2025.127892

Sreeram, R., Adithya Krishna, S., Kumar, A. S., Remya, S., & Cho, Y. Y. (2026). Soil moisture monitoring technologies in smart agriculture: A comprehensive review. *Farming System*, *4*(2), 100189. https://doi.org/10.1016/j.farsys.2025.100189

Stark, G., Weissgerber, M., Fernández, N., Quintero-Uribe, L. C., Giergiczny, M., Poulsen, N. R., Villar, N., Mols, B., Bakker, E. S., Smith, A. M., Winkel, G., Alagador, D., Rey-Benayas, J. M., Espelta, J. M., Selwyn, M., Brotons, L., Kluvankova, T., Brnkalakova, S., Kloibhofer, J., … Pereira, H. M. (2026). Toward climate-smart rewilding: An integrated framework for biodiversity, climate change, and society. *One Earth*, *9*(6), 101704. https://doi.org/10.1016/j.oneear.2026.101704

Surekha, R., Sampath, S., Dhinakaran, M., Kumar, B., & Jebastin, P. (2026). Chapter 31—Integrating sustainable practices in climate-smart agriculture and adaptation strategies. In T. Sarkar & S. Smaoui (Eds.), *Health, Nutrition and Sustainability* (pp. 695–713). Academic Press. https://doi.org/10.1016/B978-0-443-32920-3.00033-1

Tesfa, A., Taye, M., Haile, A., Nigussie, Z., Najjar, D., Mekuriaw, S., van Dijk, S., Wassie, S. E., Wilkes, A., & Solomon, D. (2025). Systematic review on the impacts of community-based sheep breeding programs on animal productivity, food security, women's empowerment, and identification of interventions for climate-smart systems under the extensive production system in Ethiopia. *Small Ruminant Research*, *253*, 107622. https://doi.org/10.1016/j.smallrumres.2025.107622

Tonnang, H. E. Z., Tepa-Yotto, G. T., Sokame, B. M., Winsou, J. K., Tamò, M., & Djouaka, R. F. (2025). Roadmap for mainstreaming integrated pest management (IPM) into a climate smart one-health (CS-OH) framework. *One Health*, *20*, 101084. https://doi.org/10.1016/j.onehlt.2025.101084

Tripathy, S., Das, S., Mahapatra, S., Sahoo, J. P., Dweh, T. J., Mahapatra, M., & Mishra, S. (2026). Chapter 3—The role of artificial intelligence in developing climate-resilient and smart agriculture. In J.-T. Chen (Ed.), *AI Technologies for Crop Breeding* (pp. 45–61). Academic Press. https://doi.org/10.1016/B978-0-443-33633-1.00003-4

Vishvanathan, V., Thalagala, N. T., Thibbotuwawa, A., Nielsen, P., & Bocewicz, G. (2025). Barriers to the Adoption of Climate-Smart Agriculture Strategies in the Horticulture Supply Chain. *15th IFAC Workshop on Intelligent Manufacturing Systems IMS 2025*, *59*(24), 362–367. https://doi.org/10.1016/j.ifacol.2025.11.892

Wang, R., Li, C., An, Z., & Chang, S. X. (2026). Climate-smart forestry: Strategies, policies, and technologies for enhancing climate change mitigation and ecosystem sustainability. *Climate Smart Agriculture*, *3*(2), 100110. https://doi.org/10.1016/j.csag.2026.100110

Wang, W., & Li, Q. (2025). Smart farming revolution: Leveraging machine learning for sustainable agriculture. *Journal of Cleaner Production*, *527*, 146434. https://doi.org/10.1016/j.jclepro.2025.146434

Wereta, M. S., Ayele, Z. A., & Damtie, Y. A. (2026). Analyzing the synergies and trade-offs of climate-smart agriculture practices on food security and resilience in Guba Lafto Woreda, Ethiopia. *Climate Services*, *43*, 100676. https://doi.org/10.1016/j.cliser.2026.100676