



Climate change and global agricultural resilience: A bibliometric and science-mapping review

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DOI: <https://doi.org/10.66856/ijaps.2026.8.3.8283>

Abstract

Accelerating climate variability—marked by extreme temperatures, precipitation anomalies, and compounding agro-ecological shocks—poses an existential risk to global food systems. "Agricultural resilience," defined as the capacity of farming systems to absorb disturbances, adapt practices, and transform under persistent climate stress, has emerged as a foundational sustainability paradigm. Despite expanding literature, research remains fragmented across agronomic, ecological, and socio-economic domains. This study delivers a bibliometric and science-mapping review of 4,820 peer-reviewed articles (2000–2024) retrieved from the Web of Science Core Collection and Scopus. Employing Bibliometrix and VOSviewer, we map publication trajectories, cross-national collaboration networks, co-word clusters, and thematic evolutions. Results demonstrate an exponential publication surge following the 2015 Paris Agreement and the UN Sustainable Development Goals (SDGs 2 and 13). Spatial analysis reveals a pronounced epistemic divide: high-income economies lead conceptual architecture and capture funding, while vulnerable regions in Sub-Saharan Africa and South Asia serve primarily as empirical test sites. Co-word clustering identifies four foundational knowledge pillars: (1) crop stress genomics, (2) soil-water agroecology, (3) socio-ecological governance, and (4) digital agro-informatics. We conclude by highlighting key research frontiers to guide transformative resilience policies.

Keywords: Climate change, Agricultural resilience, Bibliometrics, Science mapping, VOSviewer, Climate-Smart Agriculture, Food security

Introduction

Anthropogenic climate change threatens the stability of global agriculture. As documented by the Intergovernmental Panel on Climate Change (IPCC, 2022), intensifying droughts, heatwaves, and monsoonal shifts impair crop yields and degrade arable soils (Lobell *et al.*, 2011; Ortiz-Bobea *et al.*, 2021) [7, 9]. These impacts fall disproportionately on smallholders across the Global South, who produce roughly a third of the world's food supply with limited economic buffers (Ricciardi *et al.*, 2018) [10]. Consequently, scholarship has transitioned from reactive "vulnerability reduction" toward systemic "agricultural resilience." Grounded in complex adaptive systems theory (Folke *et al.*, 2010; Holling, 1973) [3, 4], agricultural resilience captures a farming system's capacity to absorb climatic shocks (absorptive capacity), incrementally adjust practices (adaptive capacity), and reorganize fundamentally when historical configurations become ecologically unviable (transformative capacity) (Meuwissen *et al.*, 2019; Tendall *et al.*, 2015) [8, 11]. Concurrently, Climate-Smart Agriculture (CSA) frameworks integrate productivity, adaptation, and mitigation (FAO, 2013; Lipper *et al.*, 2014) [6]. However, rapid growth has created conceptual silos between crop genetics, landscape ecology, rural sociology, and digital agro-informatics. Bibliometrics and science mapping offer quantitative, reproducible tools to decode macro-level knowledge structures and chart conceptual trajectories (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010) [1, 12]. This review synthesizes global scholarship from 2000 to 2024 to delineate publication dynamics, intellectual structures, and emergent frontiers.

Data and Bibliometric Methodology

A PRISMA-compliant multi-database retrieval protocol was executed across the Web of Science (WoS) Core Collection and Scopus combining climate drivers with resilience concepts:

$S = ("climate\ change" \vee "global\ warming") \wedge ("agricultural\ resilience" \vee "climate\ smart\ agriculture" \vee "agroecosystem\ resilience")$
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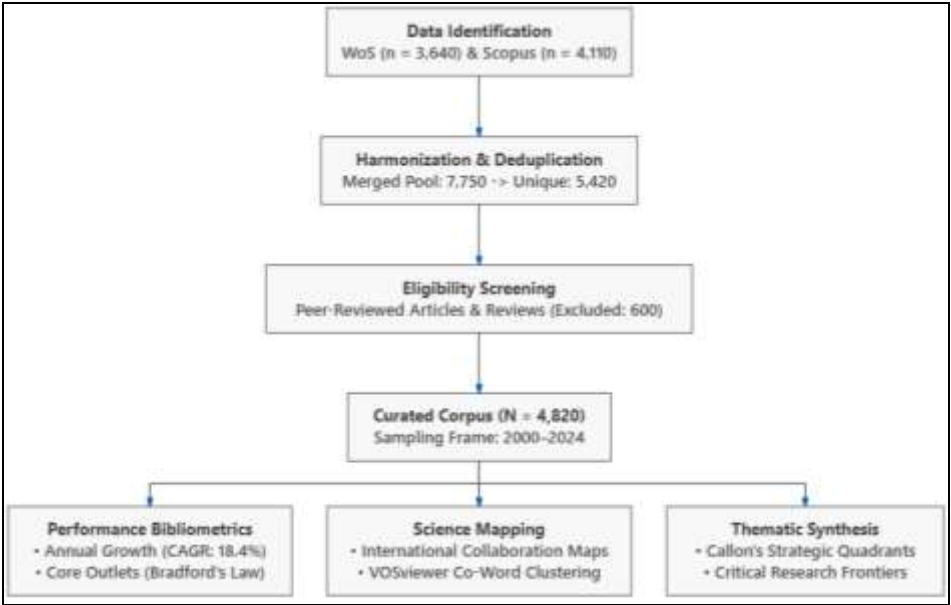
The sampling window spanned 2000–2024, restricted to English-language peer-reviewed articles and reviews. Following automated deduplication and manual screening, a curated corpus of $N=4,820$ records was established. Growth trajectories and Bradford's core journals were processed in R (Bibliometrix). International collaboration networks and keyword co-occurrences were mapped in VOSviewer (v1.6.20) using fractional counting and association strength normalization. Thematic centrality and density were evaluated using Callon's clustering algorithm.

Spatiotemporal Evolution and Collaboration Landscapes

The corpus expanded at an annual compound growth rate (CAGR) of 18.4%, rising from 28 articles in 2000 to over 740 annually by 2024 across three developmental epochs:

- 1. Incipient Phase (2000–2009):** Characterized by biophysical crop-yield sensitivity modeling under early IPCC emission scenarios.
- 2. CSA Emergence Phase (2010–2015):** Catalyzed by the FAO's Climate-Smart Agriculture framework and CGIAR-CCAFS initiatives.

3. **Systems Transformation Phase (2016–2024):** Accelerated by the Paris Agreement and UN Sustainable Development Goals (SDG 2 and 13), highlighting socio-ecological resilience, agroecology, and digital tools.



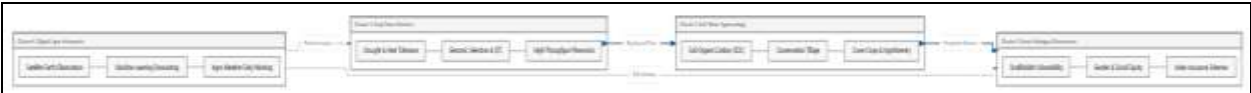
In accordance with Bradford's Law, one-third of all articles are concentrated in a core nucleus of journals: Agricultural Systems, Global Food Security, Agronomy for Sustainable Development, Climatic Change, and Science of the Total Environment.

Country	Articles (NN)	Citations	Core Focus	Epistemic Role
United States	1,142	54,200	Macro-modeling, genomics, policy	Global funding & analytical anchor
China	985	36,800	Water-saving agronomy, soil carbon	National empirical & tech hub
United Kingdom	480	24,100	Socio-ecological systems, CSA	International project coordinator
India	422	14,300	Smallholder adaptation, breeding	Major vulnerable field observatory
Australia	390	19,800	Dryland farming resilience	Arid-zone systems leadership

Spatial co-authorship analysis reveals notable structural disparity. High-income economies govern conceptual design and research grants, whereas Sub-Saharan Africa and South Asia serve primarily as empirical testbeds. Local researchers in vulnerable nations hold lead authorship positions in under 35% of published field studies, reflecting persistent epistemic inequities in global scientific governance.

Science Mapping: Thematic Clusters and Knowledge Structures

High-dimensional keyword co-occurrence analysis resolves the intellectual landscape into four primary, mutually reinforcing thematic clusters.



Cluster 1: Crop Stress Physiology and Genomic Breeding (Red)

Core terms: drought tolerance, heat stress, marker-assisted breeding, QTL mapping, phenomics. This biophysical cluster explores plant stress adaptation mechanisms, including cellular osmoregulation, root plasticity, and transpiration efficiency. High-throughput phenotyping and CRISPR-Cas9 genome editing are applied to breed "climate-ready" cultivars of staple crops (maize, rice, wheat, pearl millet) capable of withstanding acute thermal and hydrological shocks.

Cluster 2: Soil-Water Nexus and Conservation Agronomy (Green)
Core terms: conservation agriculture, soil organic carbon (SOC), no-till, crop diversification, agroforestry. Operating at farm and watershed scales, this cluster evaluates regenerative practices that safeguard soil and

water integrity. Accruing soil organic carbon enhances moisture retention, mitigates erosive runoff, and sustains microbial biodiversity. Concurrently, agroforestry and conservation tillage sequester carbon, aligning local adaptation with global mitigation.

Cluster 3: Socio-Ecological Systems and Smallholder Livelihoods (Blue)
Core terms: socio-ecological systems, adaptive capacity, smallholders, gender equity, index insurance. Bridging agronomy with rural sociology and economics, this cluster examines how land tenure, gender equity, institutional capital, and market access shape adaptive capacity. Inquiries evaluate novel risk-transfer instruments, such as satellite-indexed weather insurance, and stress

integrating indigenous knowledge into community adaptation planning.

Cluster 4: Digital Agriculture and Predictive Agro-Informatics (Yellow)

Core terms: remote sensing, Google Earth Engine, NDVI, machine learning, early warning systems. This technological frontier integrates satellite earth observation (Sentinel, Landsat), IoT sensors, and machine learning models. Research focuses on tracking crop water stress, forecasting seasonal yield deviations, and delivering mobile agro-meteorological advisories to facilitate proactive farm management.

Thematic Evolution and Strategic Quadrant Analysis

Mapping Callon's Centrality (external relevance) against Callon's Density (internal conceptual cohesion) structures the literature into four strategic quadrants:

- 1. Motor Themes (High Centrality, High Density):** Climate-Smart Agriculture (CSA), soil organic carbon dynamics, and drought-tolerant cultivar adoption. These represent well-funded, mature core pillars driving the field.
- 2. Basic Themes (High Centrality, Low Density):** Food security, vulnerability metrics, and water resource management. These serve as foundational concepts linking diverse sub-disciplines.
- 3. Niche Themes (Low Centrality, High Density):** Molecular QTL pathways, hyperspectral phenomics, and controlled-environment agriculture. Though internally rigorous, their narrow focus remains loosely coupled to broader rural development frameworks.
- 4. Emerging/Declining Themes (Low Centrality, Low Density):** Traditional micro-catchment harvesting exhibits declining bibliometric frequency, whereas AI-driven agro-meteorological advisories, circular bioeconomy models, and loss-and-damage climate finance represent rapidly rising frontiers.

Critical Knowledge Gaps and Future Research Directions

This science-mapping review identifies three urgent research imperatives:

1. Overcoming the Incremental–Transformative Gap

Over 75% of documented field studies assess incremental adaptations (e.g., adjusting sowing dates, adopting slightly earlier-maturing cultivars). Because projected warming will breach biophysical thresholds, research must pivot toward transformative resilience—including cross-regional crop substitution (promoting resilient orphan crops like teff, sorghum, and cowpea) and land-use restructuring.

2. Coupled Biophysical-Socioeconomic Modeling:

Biophysical yield simulations routinely treat institutional governance as static, while socioeconomic assessments frequently lack downscaled agro-hydrological inputs. Developing integrated agent-based models coupled with micro-climatic simulations is critical for realistic policy forecasting.

3. Democratizing Digital Agro-Informatics

Despite digital agriculture's expansion, smallholder adoption remains hindered by high capital costs, proprietary software locks, and rural connectivity deficits. Research must prioritize frugal, open-source, mobile-first advisory tools designed for resource-constrained farming communities.

Conclusion and Policy Implications

This bibliometric and science-mapping review documents the evolution of agricultural resilience from a narrow crop-science discipline into an integrated socio-ecological and technological domain. Achieving durable food system resilience requires transcending isolated technological fixes. Policy frameworks must: (1) redirect agricultural subsidies toward agro-ecological practices that restore natural soil-water buffers; (2) foster equitable South–North research partnerships where smallholders co-produce adaptation strategies; and (3) establish multilateral parametric climate finance mechanisms to de-risk farming systems before catastrophic thresholds are reached.

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