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Review of the ecological impacts of cotton cultivation and the displacement of production areas

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Review of the ecological impacts of cotton cultivation and the displacement of production areas

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Abstract
Cotton cultivation plays a pivotal socio-economic role in many developing countries. However, its expansion and spatial displacement raise growing concerns regarding land-use change and ecological sustainability under climate change. This study provides a bibliometric analysis of literature on ecological impacts of cotton cultivation and shifting production areas. Drawing from the Scopus and Web of Science databases, 4,853 documents published between 1980 and 2026 were analyzed using performance indicators and advanced science mapping techniques implemented with the Bibliometrix R package. The results reveal a steady growth of scientific output, characterized by robust international collaboration and increasing reliance on remote sensing and spatial analysis methods. However, the literature remains geographically and thematically unbalanced, with a concentration in Asia and an under-representation of Sub-Saharan Africa. Conceptually, research is predominantly structured around cotton production, land-use change, and climate change, while biodiversity and soil degradation are often treated as secondary or fragmented components. Furthermore, most studies adopt retrospective or descriptive approaches, with a notable scarcity of integrated prospective modelling frameworks. This review identifies critical research gaps, including the paucity of climate-gradient-based analyses and the absence of forward-looking, multidisciplinary approaches integrating climatic, ecological, agronomic, and socio-economic drivers. In this context, Burkina Faso emerges as a particularly relevant case study due to its pronounced North-South climatic gradient, strong dependence on cotton production, and vulnerability to climate change.
This study highlights the need for integrated assessments in order to better anticipate the ecological impacts of cotton zone displacement and to support sustainable land-use planning and policy-making in Africa.
Keywords: Bibliometric analysis, Cotton cultivation, Land-use change, Science mapping.

Introduction

Cotton cultivation holds a strategic position in global agriculture due to its economic, social and industrial significance [1], [2], [3]. However, it remains one of the most resource-intensive agricultural systems, exerting substantial pressures on soils, water resources, biodiversity, and climate [4], [5], [6]. In recent decades, the spatial distribution of cotton-growing areas has undergone major transformations, reflecting a profound reconfiguration of agricultural production systems on a global scale [7], [8]. In industrialized countries, these shifts have often resulted in a pronounced contraction of cotton-growing areas. [9], [10]. In the United States, for instance, harvested cotton acreage declined by nearly 50% between 2005 and 2009 (approximately 2.5 million hectares) primarily due to conversion to more profitable crops such as maize [11]. Such crop substitutions have led to significant changes in land use, water withdrawals patterns, and agrochemical runoff, with environmental impacts varying across regions [12], [13], [14].

Conversely, in developing regions, particularly in sub-Saharan Africa and Brazil, the displacement or expansion of cotton cultivation into new territories has been coupled with significant degradation of natural habitats, increased ecosystems fragmentation, and rising pressures on biodiversity [15], [16], [17], [18], [19], [20], [21]. The agricultural intensification associated with these dynamics also contributes to soil erosion, long-term fertility loss, and a heightened dependence on inputs, there by exacerbating land degradation processes [22], [23], [24].

Water resources represent another critical challenge in the relocation of cotton-growing areas. Shifts in crop location modify pollutant loading, generating contrasting effects depending on hydroclimatic contexts and cropping systems [25], [26], [27]. Furthermore, Life cycle assessments (LCA) method has permitted to identify complex climate impacts, where direct emissions from cotton production may be partially offset by indirect land-use changes or co-product substitution, rendering the overall assessment of climate effects particularly challenging [12].

Various methodological frameworks have been employed to understand these dynamics, including attributional and consequential life cycle analysis, spatialized hydrological modeling, bio-economic optimization and scenario analysis [12]. Despite these advances, the literature remains fragmented and predominanted retrospective, limiting an integrated and prospective understanding of the ecological trajectories associated with the displacement of cotton-growing areas [12].

Consequently, the displacement of cotton production areas is not a simple geographical transfer; it triggers cascading ecological impacts involving complex interactions between climate, land use, natural resources and socio-economic dynamics. A rigorous and structured synthesis of existing knowledge is therefore essential to inform land-use planning and management strategies.

In this context, this study aims to provide a synthetic and critical analysis of the scientific literature devoted to the ecological impacts of cotton-growing areas displacement globally, with a specific focus on Africa. The specific objectives are (i) to analyze the scientific production relating to the ecological impacts of cotton-growing areas displacement and (ii) to highlight research gaps and methodological perspectives for an integrated and sustainable assessment of cotton systems.

2. Materials and Methods

2.1. Study design

This study employs a quantitative bibliometric approach to analyze the scientific output related to the ecological impact of cotton-growing areas displacement. The analysis specifically focuses on the interactions between land-use change, biodiversity, land degradation, water resources, and climate change. Bibliometric analysis facilitates the identification of temporal dynamics, key scientific stakeholders, intellectual structures and emerging trends within this research field.

2.2. Data sources

This bibliometric analysis was conducted using a multi-source dataset compiled from Scopus (Elsevier), the Web of Science (WoS) Core Collection (Clarivate Analytics) and Google Scholar to ensure comprehensive coverage. Literature suggests that relying on a single database may introduce bias, as coverage and citation representation vary across platforms; thus, combining multiple sources enhances the robustness and completeness of the science mapping [28], [29].

Scopus served as the primary data source due to its broad multidisciplinary coverage (including environmental sciences, agriculture, and geography) and its high-quality, standardized bibliographic metadata, which are well-suited for advanced bibliometric analysis [28]. Previous research has underscored the strength of Scopus for large-scale scientometric studies owing to its extensive publications index and consistent metadata structure [30], [31].

The Web of Science Core Collection was used to complement Scopus by incorporating high-impact journals and historical publications that might be under represented in a single database. Furthermore, Google Scholar was utilized to retrieve relevant grey literature, such as technical reports, and regionally studies. Empirical comparisons demonstrate that Google Scholar often captures a broader set of document types and citations, which are essential for identifying regionally significant research from under represented areas like Sub-Saharan Africa [29].

2.3. Search strategy and inclusion criteria

The search was performed using the “Title, Abstract and Keywords” fields to maximize thematic relevance [28], [29], [32], [33], [34]. The Boolean search query was structured as follows: (("cotton cultivation" OR "cotton belt shift" OR "culture du coton" OR "production cotonnière") AND ("land use change" OR "LULCC" OR "changement d'utilisation des terres" OR "changement d'occupation des sols") AND ("biodiversity loss" OR "ecosystem degradation" OR "soil degradation" OR "soil erosion" OR "water use" OR "water scarcity" OR "perte de biodiversité" OR "dégradation des écosystèmes" OR "dégradation des sols") AND ("climate change" OR "climate variability" OR "climate impacts" OR "changement climatique" OR "variabilité climatique").

This equation integrated central terms describing cotton’s spatial dynamics, land use changed concepts, key ecological impacted variables, and the cross-cutting framework of climate change. Inclusion criteria was limited to scientific articles and review published between 1980 and 2026 that explicitly addressed cotton production and its ecological footprint.

2.4. Data extraction and preparation

Metadata were exported in CSV, BibTex, and plain text formats, including authors, titles, publication years, abstracts, keywords (author and indexed), affiliations and citations count [32]. All records were harmonized, deduplicated and standardized prior to analysis. This data cleaning process ensures the reliability of bibliometric indicators and mitigates biases associated with selective database coverage.

2.5. Analysis methods and tools

The analysis was divided into two main components:

- performance analysis: evaluating annual evolution publication trends, prominent journals, influential authors/institutions, and major contributing countries;
- science mapping: conducting keywords co-occurrence analysis, co-citation networks, and thematic clusters mapping [29], [31], [33].

Bibliometric analyses and visualizations were performed using R software (version 4.5.2) with the bibliometrix package [32], [35]. Microsoft Excel was utilized for initial data management and pre-processing.

3. Results

3.1. Descriptive overview of the bibliometric dataset

The bibliometric analysis is based on a dataset of 4,853 documents indexed in the Scopus and Web of Science databases, published between 1980 and 2026, and spanning a total of 91 scientific sources.

Research articles represent the dominant document type (n = 4488), followed by review papers (n = 348), while other document formats remain marginal. The dataset includes contributions from 19,962 authors (Table1).

Table 1. Main information about data

Timespan	1980: 2026
Documents	4,853
References	907
DOCUMENT TYPES	
article	4,488
book	5
book chapter	12
review	348

3.2. Temporal evolution of scientific production

The annual scientific output follows a long-term upward trajectory, discernible in three distinct phases. During the initial period (1980 to the early 2000s), publication volume remained limited and sporadic, representing an exploratory phase primarily focused on agricultural expansion and land management. A steady increase is observed from the mid-2000s onward, coinciding with heightened global concern regarding land degradation and environmental sustainability (Figure 1).

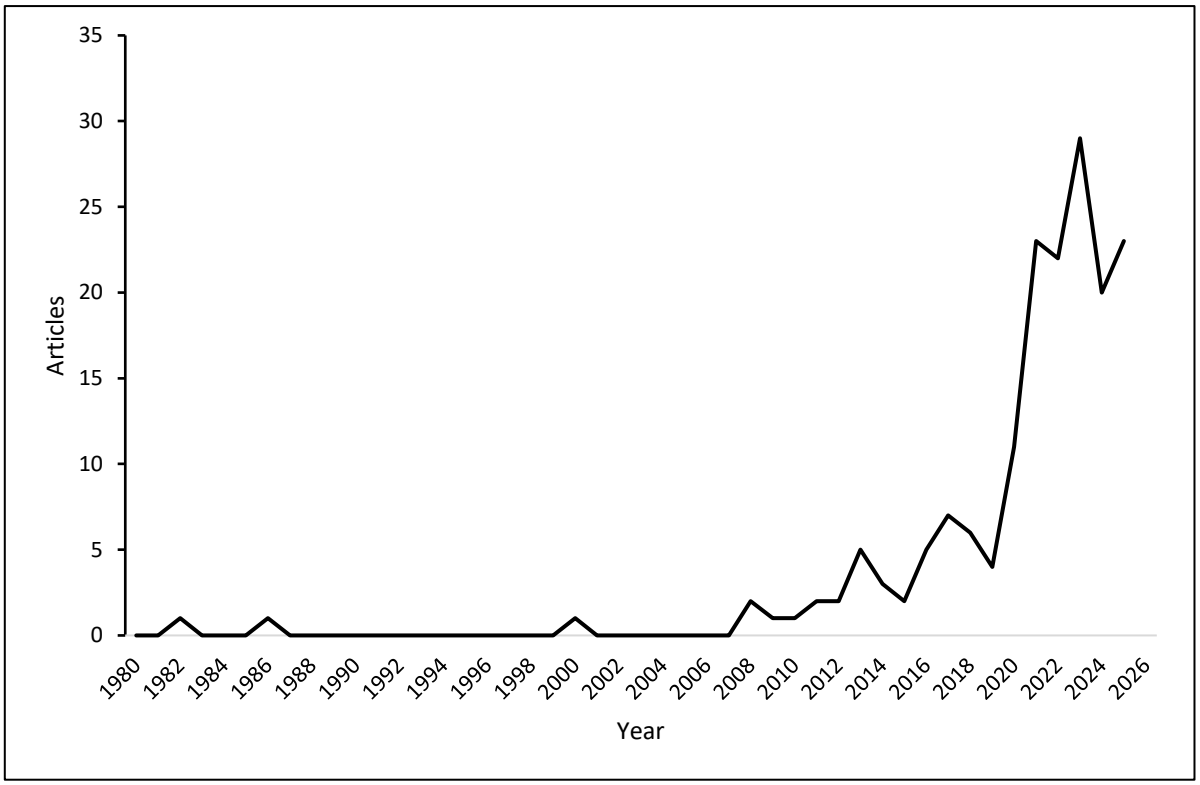


Figure 1. Annual scientific production of the ecological impacts of cotton cultivation

A marked acceleration in output occurred after 2015, signaling a structural shift toward climate-change-oriented and sustainability-driven research agendas. This recent surge aligns with the widespread adoption of remote sensing technologies, improved accessibility to high-resolution spatial datasets, and the increasing policy relevance of land-use dynamics within agricultural systems. Overall, this temporal pattern suggests that the field has transitioned from an emergent state toward a mature and consolidated stage of scientific inquiry (Figure 1).

3.4. Geographic distribution of scientific production

3.4.1. Global patterns

The country-level analysis reveals a pronounced geographic concentration of scientific production, led by the United States and China, which are characterized by relatively low levels of international collaboration (Figure 2). The marginal representation of West African cotton-producing nations underscores a significant disparity between the regions generating scientific evidence and those most vulnerable by cotton- induced ecological pressures (Figure 2).

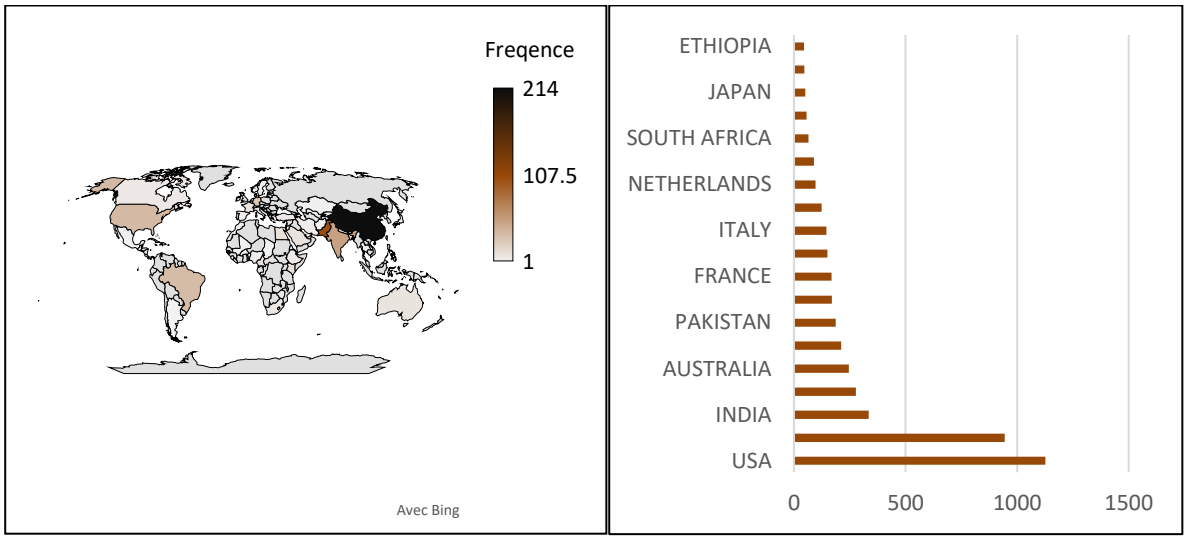


Figure 2 : Countries scientific production on ecological impacts of cotton-growing areas

3.4.2: Link between production by country

The Three-Fields Plot highlights a strong dominance of China in scientific production, underscoring its central role in shaping research themes and publication outlets. This dominance is primarily associated with methodological approaches such as remote sensing, reflecting a strong technological orientation of the field. The close connections between China and themes such as climate change indicate that research is largely framed within broader global environmental change narratives. In contrast, the limited diversity of contributing countries reveals a concentration of scientific production within a small number of dominant nations. Overall, the network structure shows a strong coupling between leading countries, technology-driven themes, and journals, with limited representation of context-specific ecological issues, particularly those related to West Africa (Figure 3).

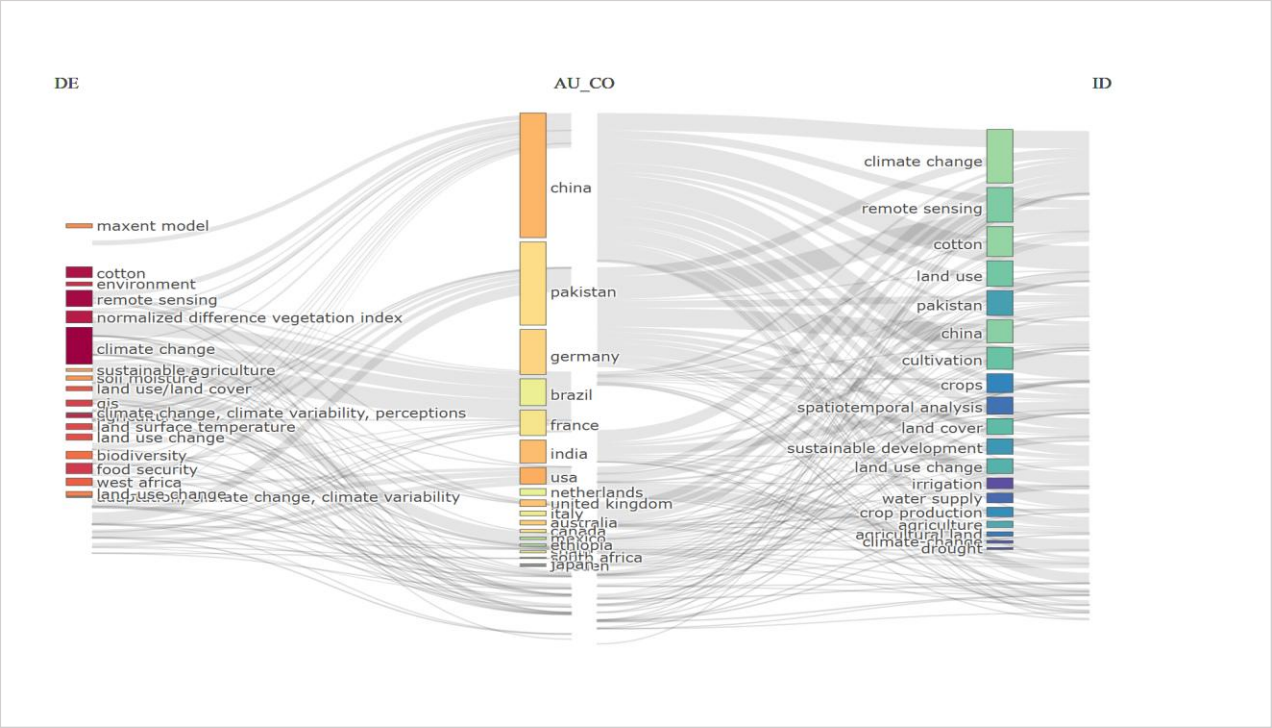


Figure 3: Three fields plot on Ecological Impacts of Cotton-Growing Areas

3.4.3. Focus on Africa

In Africa, research on the ecological impacts of cotton cultivation is much more carried out in South Africa (19,06%). Nations such as Burkina Faso, Mali, Benin, Cameroon, and Ethiopia make only marginal contributions to the corpus (9,8%) (Figure 4).

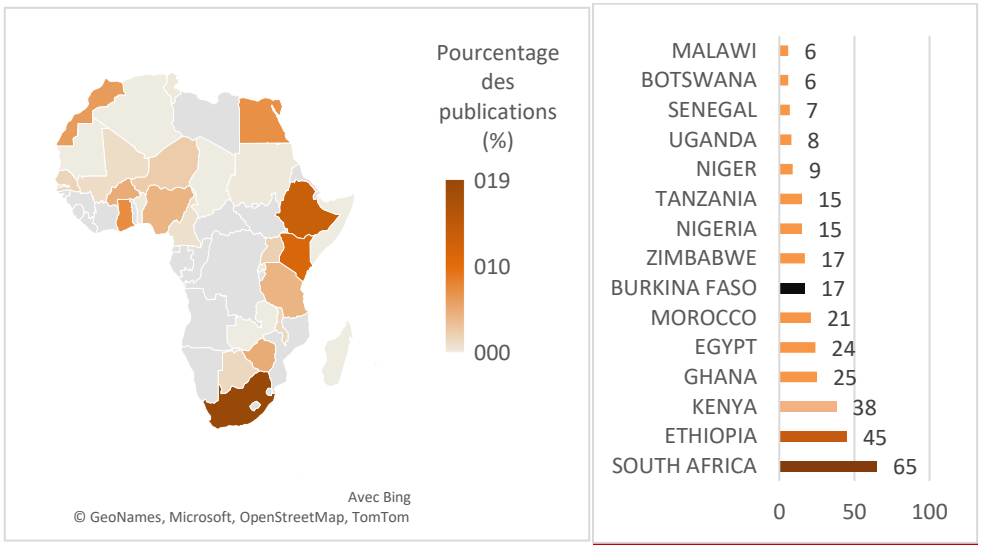


Figure 4: Most contributed countries in the ecological impacts of cotton cultivation

3.5. Lexical structure of the research field of the ecological impacts of cotton cultivation

The lexical analysis, based on keyword frequency and word cloud visualization, confirms that “cotton,” “land use change,” and “climate change” constitute the conceptual core of the literature (Figure 5). Terms associated with remote sensing, GIS, and spatial analysis are also highly prominent, reflecting the field’s strong methodological orientation toward geospatial technologies.

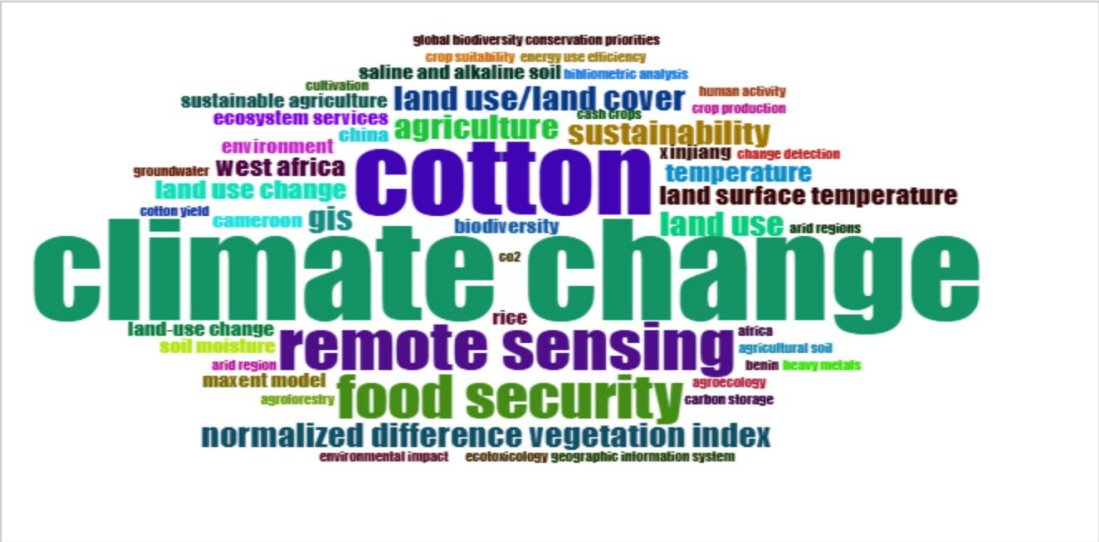


Figure 5: Word cloud of the ecological impacts of cotton cultivation

3.6. Conceptual structure: keyword co-occurrence network

The keyword co-occurrence analysis reveals a highly structured conceptual network organized around a central cluster that interlinks cotton cultivation, land-use dynamics, and climate change. This core cluster is flanked by secondary clusters addressing sustainability, food security, and spatial methodologies.

Although ecological themes are present across these clusters, their relatively peripheral positioning indicates that they remain less integrated into the predominant research paradigms. The network architecture suggests a progressive convergence toward integrated assessments; however, ecological variables continue to play a secondary role compared to production-oriented and spatial dynamics (Figure 6).

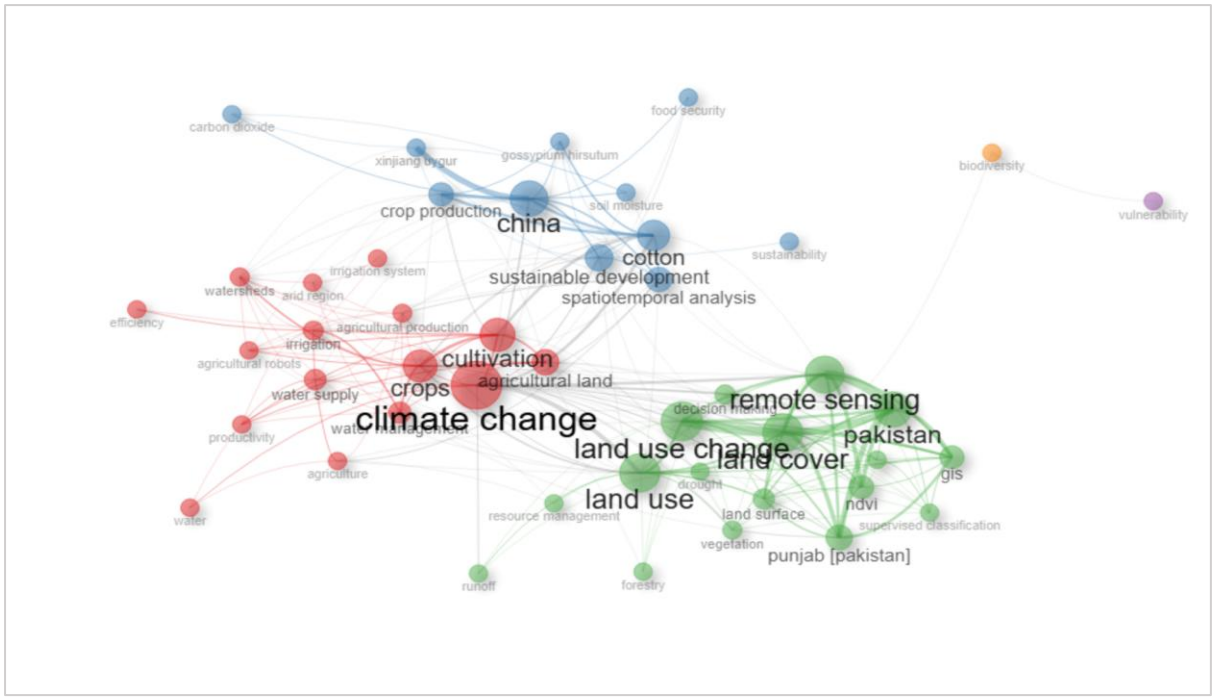


Figure 6: Cowordnet on Ecological Impacts of Cotton-Growing Areas

3.7. Thematic map: maturity and relevance of research themes

Cotton cultivation and climate change emerge as motor themes, characterized by high relevance and robust internal development. These themes anchor the field and bridge various research streams.

Land-use change and agriculture appear as basic and transversal themes, providing conceptual foundations but exhibiting moderate internal development. Conversely, remote sensing and sustainability are identified as emerging themes, reflecting ongoing methodological and conceptual transitions. Notably, themes focused specifically on ecological impact tend to occupy niche or emerging positions, signifying their growing but still limited integration into the broader discourse (figure 7).

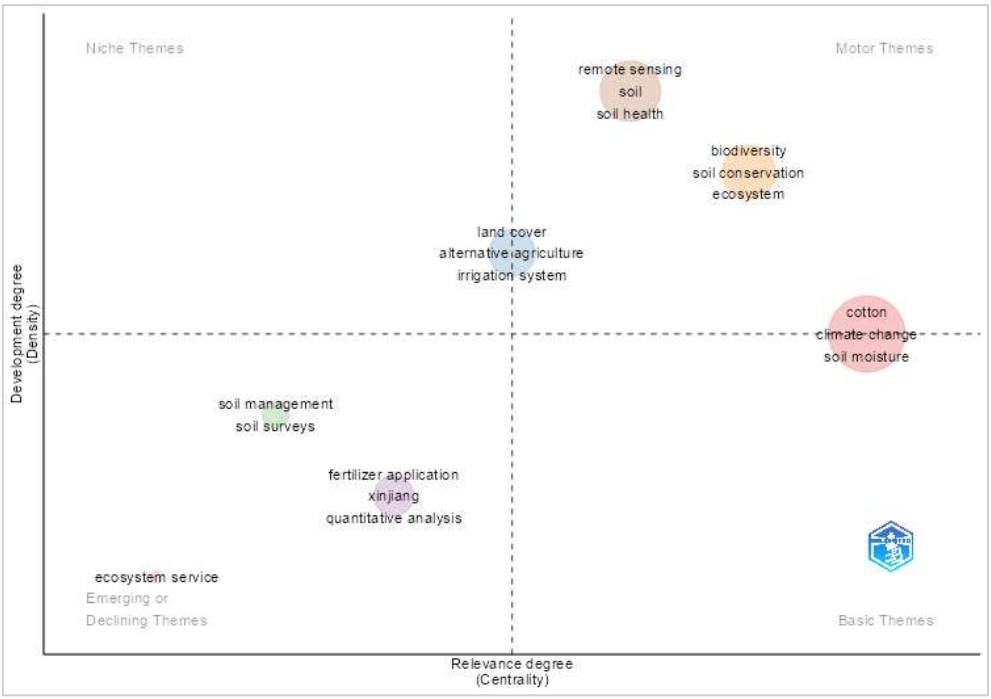


Figure 7: Thematic map in maturity and relevance of research themes on Ecological Impacts of Cotton-Growing Areas

3.8. Thematic evolution and research trajectories on Ecological Impacts of Cotton-Growing Areas

The analysis of thematic evolution highlights a distinct shift in research focus over time. Early scholarship (pre-2010) primarily addressed land-use change and agricultural expansion through a descriptive lens. Subsequent periods witnessed the integration of cotton-specific life cycle analyses, followed by a rapid surge in themes related to climate change, sustainability, and remote sensing after 2020 (Figure 9).

This trajectory reflects a paradigm shift toward spatially explicit and climate-informed research, increasingly aligned with global sustainability and policy-oriented objectives. Overall, the thematic evolution illustrates a progression from sectoral, process-oriented analyses toward climate-driven and methodologically sophisticated approaches. However, the limited centrality of land-use dynamics and the persistent fragmentation between climatic, ecological, and spatial dimensions indicate unresolved gaps in the field. These gaps are particularly salient for cotton-producing regions in Sub-Saharan Africa, where sharp climatic gradients and land-use transitions play a critical role in shaping ecological outcomes (Figure 8).

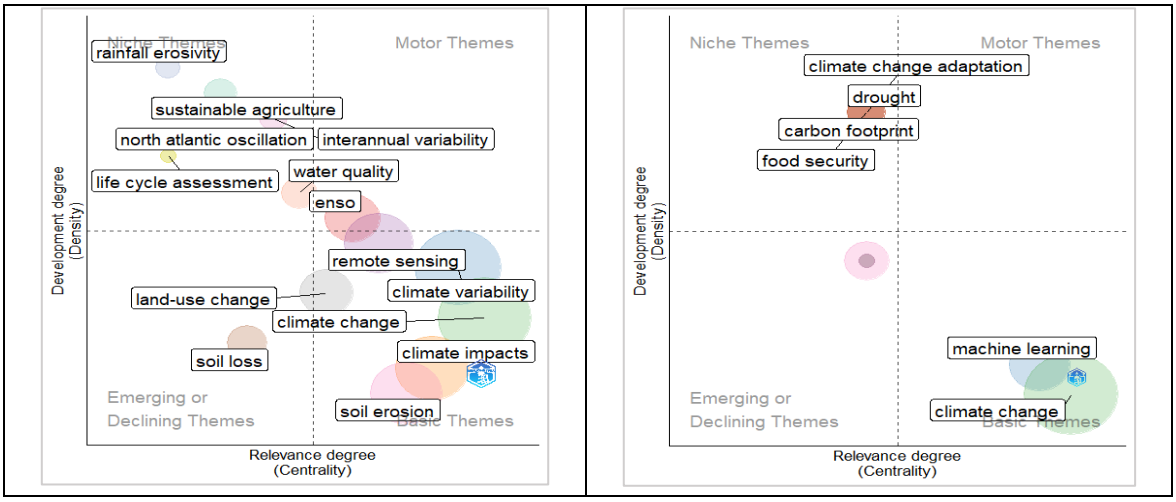


Figure 8: Thematic evolution and research trajectories on Ecological Impacts of Cotton-Growing Areas

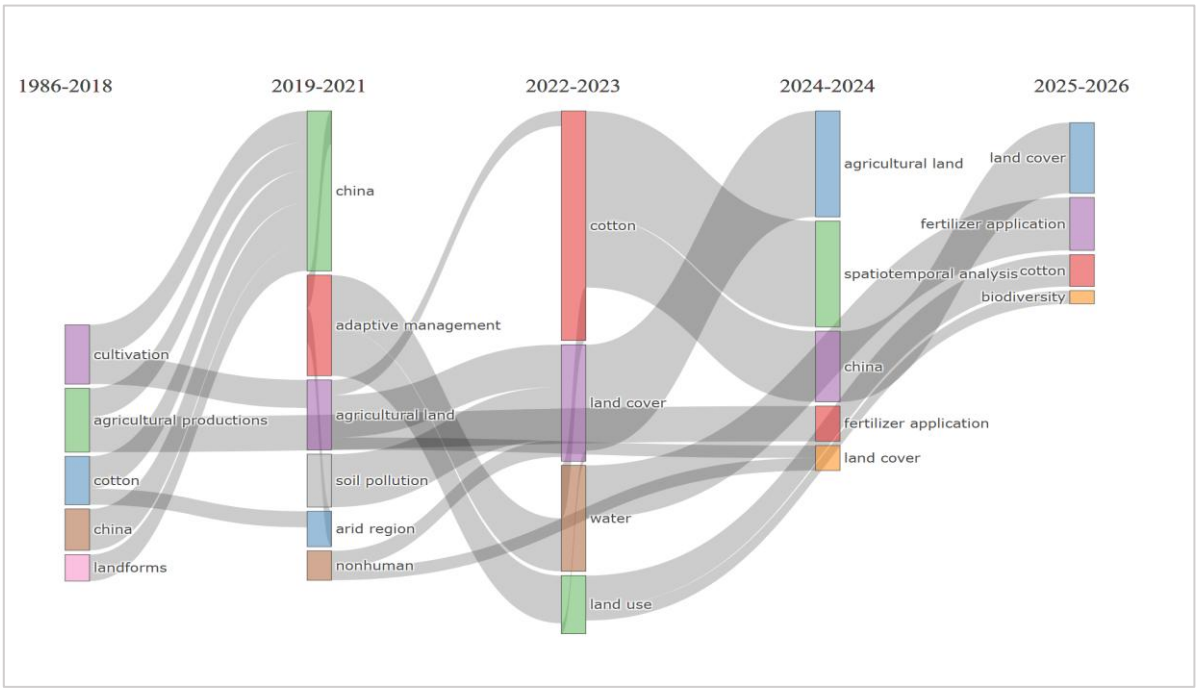


Figure 9: Thematic evolution on Ecological Impacts of Cotton-Growing Areas

Figure 10 depicts the temporal evolution of research themes, organized into four distinct periods. The initial phase is characterized by a predominance of agronomic studies focused on cotton production, often spatially localized, with a notable concentration in Brazil.

The second phase maintains this production-oriented focus, while reflecting a geographical shift marked by the growing dominance of China in scientific output.

During the third phase, research priorities expand toward climate change and its ecological impacts, with remote sensing and land-use change analysis becoming central methodological tools.

In the most recent phase, attention increasingly shifts toward the environmental consequences of agricultural practices, particularly fertilization, with a focus on soil properties such as fertility, conservation, and moisture. This transition reflects a broader movement toward more integrated assessments of cotton production impacts on ecosystems and soil degradation processes.

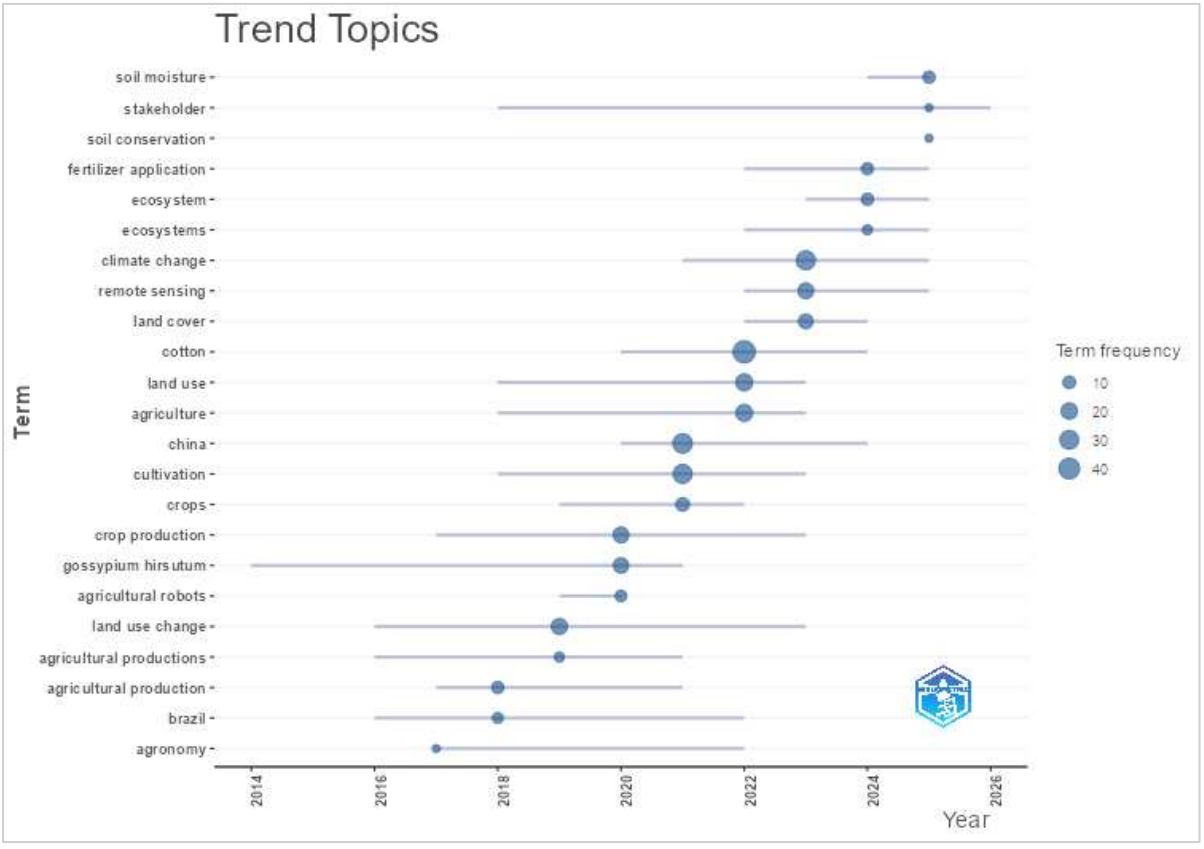


Figure 10: Trend topic on Ecological Impacts of Cotton-Growing Areas

3.9. Factorial analysis of research orientations on the ecological impacts of cotton cultivation

The factorial analysis reveals two dominant dimensions structuring the literature. The first represents a methodological gradient, contrasting mechanistic ecological and agronomic studies with spatially explicit approaches leveraging on remote sensing and GIS. The second reflects a conceptual gradient, distinguishing production-oriented research from studies emphasizing sustainability and long-term ecological impacts.

Ecological variables, specifically biodiversity and ecosystem integrity, tend to occupy peripheral positions within this factorial space. This reinforces that ecological health remains a secondary consideration within dominant research paradigms, which continue to be led by agronomic performance and spatial monitoring (Figure 11).

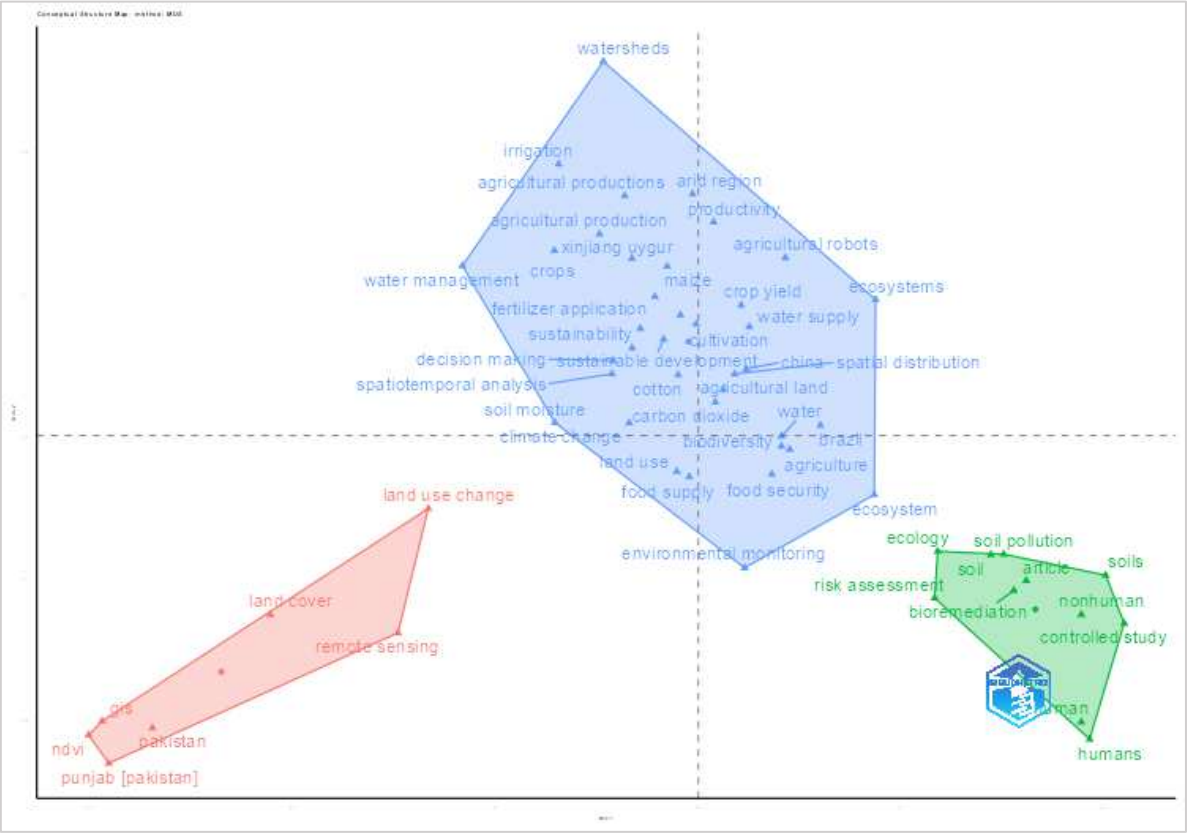


Figure 11: Factorial analysis of research evolution on Ecological Impacts of Cotton-Growing Areas

4. Discussion

4.1. Consolidation of the scientific field and dominant research in the ecological impacts of cotton-growing areas

The bibliometric results indicate that research regarding the ecological impacts of cotton-growing areas has experienced sustained growth over the past four decades, with a marked acceleration since the mid-2010s. This trajectory reflects an increasing global recognition of the environmental challenges associated with agricultural expansion, particularly within the nexus of climate change and land degradation.

However, despite this quantitative expansion, the conceptual architecture of the field remains predominant oriented towards production-oriented and geospatial approaches [4], [36], [37], [38], [39], [40]. The literature is largely structured around

cotton agronomy, land use change and climate variability, supported by the extensive mobilization of remote sensing and geospatial tools [7], [41], [42], [43]. While these methodologies enhance the understanding of spatial dynamics and productivity, they frequently relegate ecological dimensions to a secondary status.

Furthermore, the convergence of country-level analysis and the three-fields plot reveals a structural asymmetry. Developed nations, specifically the USA and China, dictate research agendas and central themes, while regions most vulnerable to cotton-induced ecological impacts remain marginalized in the production and dissemination of knowledge [44], [45]. This configuration results in an under-representation of local dynamics, such as the specific climatic gradients, land uses patterns and socio-ecological vulnerabilities characteristic of West Africa.

This asymmetry is partly explained by the fact that research on the ecological impacts of cotton-growing areas is largely influenced by methodological approaches developed in Asia and the countries of the North [28]. Most of work favors technical and environmental analyses, often sectoral [46], [47]. They are still insufficiently integrated into multidisciplinary frameworks combining climatic, biological, pedological, water and socio-economic dimensions [48] . Moreover, the lack of studies explicitly focused on West Africa and Burkina Faso among the dominant studies reinforces this scientific imbalance [49] .

4.2. Partial integration of environmental considerations

A critical finding of this bibliometric analysis is the lack of centrality of key ecological variables, including biodiversity, soil degradation and water resources [47], [49]. While present in the body of literature, these themes are often fragmented, addressed tangentially, or subordinated to analyse of crop yield, agricultural management.

This marginalization suggests that the literature is still struggling to adopt an integrated ecosystem-based approach, which is essential for evaluating the long-term sustainability of cotton systems. Results from co-occurrence networks and factorial analysis confirm that biodiversity and ecosystem health occupy a peripheral position within dominant paradigms, limiting the field's capacity to offer holistic diagnoses of the trade-offs between agricultural output and ecosystem conservation.

4.3. Geographical imbalances and under-representation of West Africa

The geographical concentration of scientific output is another defining characteristic of this study. Asian, American and European institutions dominate the literature in terms of both volume and citation impact [28]. This dominance reflects both the economic importance of cotton in these regions and their substantial institutional capacity for environmental research.

Conversely, West Africa remains significantly under-represented, despite its pivotal role in global cotton markets and its extreme vulnerability to hydroclimatic shifts [50]. Nations such as Burkina Faso, Benin and Cameroon contribute marginally and primarily through multi-country collaborations, reflecting a lack of domestic scientific leadership on these themes. This imbalance creates a critical gap between the areas most exposed to the ecological degradation and those producing the evidence base, thereby limiting the contextualization and policy relevance of findings for local decision-makers.

4.4. Insufficient integrated and forward-looking approaches

A fundamental gap identified in this review concerns the prevalence of descriptive and retrospective methodologies. Most studies analyze historical or current land use dynamics without projecting of future trajectories [51].

However, the relocation of cotton-growing areas is a fundamentally dynamic process driven by complex interactions between climate, soil, water, and socio-economic drivers [52]. The scarcity of forward-looking, integrated modeling hinders the ability of research to anticipate shifts in ecologically sensitive zones and cumulative long-term impacts [49], [51]. This methodological deficit poses a significant barrier to translating scientific insights into effective climate adaptation and territorial planning policies.

4.5. The North-South Climate Gradient: An Under-Exploited Analytical Framework

The results also demonstrate that, while climate change is ubiquitous in the literature, it is rarely operationalized as a continuous structuring spatial axis, particularly in the form of climate gradients [49], [50]. This limitation is especially problematic in the Sahelian and Sudanese regions, where latitudinal aridity gradients strictly dictate water availability, soil fertility and ecosystem resilience.

In the specific context of Burkina Faso, the North-South climate gradient governs not only the crop distribution but also the displacement of cotton-growing areas toward southern wetter regions [50], [53]. However, existing studies seldom address these

dynamics through an integrated lens along this gradient. This oversight precludes the identification of critical ecological thresholds, transition zones and differentiated sustainability trajectories across varying agroclimatic zones.

4.6. Ecological Impacts and Spatial Dynamics of Cotton Cultivation in West Africa: Focus on Burkina Faso

In Africa, cotton cultivation is associated with significant environmental pressures, including land-use change, soil degradation, and biodiversity loss driven by agricultural expansion resources [47], [49]. In West Africa, these dynamics are reinforced by strong climatic variability, which influences crop suitability and drives the spatial redistribution of production systems [49], [50].

In Burkina Faso, cotton farming plays a key economic role but is also linked to declining soil fertility, increasing dependence on chemical inputs, and landscape transformation (FAO, 2021; Herrmann et al., 2020). The displacement of cotton cultivation toward more humid southern regions reflects adaptation to rainfall gradients [50], [53]

However, the literature remains largely fragmented and retrospective, with limited integration of ecological processes and spatial dynamics. This lack of integrated and spatially explicit approaches constrains the understanding of long-term impacts and limits the identification of ecological thresholds and region-specific vulnerabilities [49], [51].

4.6. Scientific justification of the case of Burkina Faso

Burkina Faso represents an exceptionally relevant case study for addressing the identified research gaps. The country exhibits a high economic reliance on cotton cultivation, a pronounced North-South climate gradient and extreme vulnerability to soil degradation, land pressure and climate variability [41].

Nevertheless, the bibliometric analysis confirms that despite these pressing challenges, Burkina Faso remains virtually absent from the international literature regarding the ecological impacts of cotton-growing areas shifts [54]. This void underscore the urgent need to develop context-specific, integrated, and spatially explicit studies capable of linking agricultural dynamics with climatic drivers and ecological responses.

4.7. Scientific and methodological implications

On a scientific level, these findings call for a paradigm shift in the study of cotton systems, moving from sectoral approaches to integrated frameworks, from static diagnoses to prospective modeling, and from generalized global perspectives to research rooted in local realities. As a result, the integration of remote sensing, land-use change modelling, climate scenarios and ecological indicators represent a promising frontier for advancing our understanding of the feedback loops between agriculture and ecosystems. From an operational standpoint, this study emphasizes the necessity of developing decision- support tools based on integrated and forward-looking analyses. In West Africa, such approaches are vital for supporting sustainable territorial planning, adapting cotton policies to hydroclimatic constraints, and preserving ecosystems integrity in the face of agricultural expansion. In summary, this bibliometric analysis characterizes an expanding scientific field that is still hampered by significant thematic, methodological and geographical imbalances. The under-representation of West Africa, the relative marginalization of ecological impacts, and the scarcity of integrated prospective analyses constitute major scientific gaps. Burkina Faso, as a country emblematic of the latitudinal shift of cotton-growing zones, offers a unique opportunity to advance research toward more holistic and sustainability-oriented analytical frameworks.

Conclusion

This bibliometric analysis provides a comprehensive overview of research on the ecological impacts of cotton cultivation, with emphasis on land-use dynamics and climate change interactions. The results indicate sustained growth and diversification of the field, supported by methodological advances and increased use of remote sensing and geospatial tools. However, important conceptual, methodological, and geographic imbalances persist. Research remains predominantly focused on production systems and land-use change. Key ecological dimensions, including biodiversity loss, soil degradation, and hydrological processes, are still insufficiently addressed. These aspects are often treated as secondary, limiting the robustness of sustainability assessments.

A major finding is the strong geographic concentration of scientific output. Asian countries, particularly China, dominate the literature. In contrast, Sub-Saharan Africa remains significantly underrepresented. This imbalance is especially critical in West Africa, where cotton plays a central socio-economic role. Despite its importance, the

region receives limited scientific attention. Burkina Faso exemplifies this gap between ecological vulnerability and research visibility.

The analysis also highlights structural limitations in current approaches. Most studies rely on retrospective and descriptive methods. There is a lack of integrative and forward-looking analytical frameworks. Complex interactions among climate variability, land-use change, and socio-ecological factors are rarely modeled comprehensively.

Burkina Faso represents a strategic case study due to its climatic gradient and economic dependence on cotton. It offers strong potential for developing spatially explicit and prospective research approaches. Overall, the study calls for a paradigm shift toward multidisciplinary and integrative frameworks. Such approaches are essential to better address sustainability challenges in cotton systems at regional and global scales.

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