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# Bibliometric Analysis of Agroforestry Research in Tropical Countries in Publications from 2010 to 2024

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**ABSTRACT**

This study aims to map the development of agroforestry research in tropical countries during the period 2010–2024 using a bibliometric approach. Agroforestry has increasingly been recognized as a multifunctional land-use system capable of integrating climate mitigation, biodiversity conservation, and rural livelihood improvement. However, the rapid growth of publications has made it difficult to comprehensively understand research trends, collaboration structures, and thematic evolution within this field. To address this gap, this study analyzes publications indexed in the Scopus database and employs VOSviewer to visualize co-authorship networks, institutional collaborations, country partnerships, keyword co-occurrence patterns, overlay visualization, and density mapping. The results indicate a significant increase in research output over the last decade, with strong international collaboration networks linking developed countries and tropical regions. The United States, United Kingdom, Germany, and India emerge as central contributors, while tropical countries such as Indonesia, Brazil, Kenya, and Ethiopia are increasingly active in global research partnerships. Thematic analysis reveals that agroforestry research is strongly centered on climate change, biodiversity, ecosystem services, and food security. Overlay visualization shows a temporal shift from earlier conservation-focused studies toward more integrated themes related to carbon sequestration, climate resilience, and smallholder livelihoods.



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## 1. INTRODUCTION

Agroforestry is a land use management system that integrates trees, crops, and sometimes livestock within the same production area to improve ecological sustainability and socio economic resilience. In tropical countries, agroforestry has long been embedded in traditional farming practices that adapt to complex environmental conditions [1]. Tropical regions such as Southeast Asia, Sub Saharan Africa, and Latin America contain a large proportion of global biodiversity while simultaneously experiencing high rates of deforestation, land degradation, soil erosion, and climate variability [2]. Within this context, agroforestry has gained increasing recognition as an approach capable of balancing agricultural productivity with environmental conservation. Research has shown that agroforestry systems contribute to soil fertility improvement, enhanced water retention, carbon sequestration, and diversified income for smallholder farmers.

These benefits make agroforestry particularly relevant for rural communities in tropical regions where economic vulnerability and ecological risks often intersect [3], [4].

In the last decade, global concern regarding climate change and sustainable development has intensified scientific interest in agroforestry. International development agendas such as the Sustainable Development Goals have positioned agroforestry as a nature based solution that supports climate mitigation, biodiversity conservation, and food security simultaneously. Tropical countries are central to these discussions due to their ecological importance and their significant contribution to global carbon cycles [5], [6]. Agroforestry practices help restore degraded landscapes, increase adaptive capacity to climate change, and strengthen sustainable livelihood systems. As a result, the volume of scientific publications addressing agroforestry has grown considerably, covering topics such as ecosystem services, climate resilience, carbon accounting, sustainable land management, and rural development policies [7].

The development of agroforestry research has also been influenced by methodological and technological advancements. Contemporary studies increasingly employ interdisciplinary frameworks that integrate agronomy, ecology, economics, and social sciences [8]. The use of remote sensing technologies, Geographic Information Systems, and spatial modeling techniques has improved the ability of researchers to evaluate agroforestry performance at farm, regional, and landscape scales. In addition, quantitative modeling and climate scenario analysis have become more common in assessing long term impacts of agroforestry systems [9]. International research collaborations have expanded as well, particularly in projects related to climate adaptation and sustainable land restoration in tropical countries. These developments illustrate that agroforestry research has evolved into a multidimensional and globally interconnected scientific field [10], [11].

Despite the rapid growth of publications, understanding the overall intellectual structure and research trajectory of agroforestry in tropical countries remains challenging. Multiple research themes such as carbon sequestration, biodiversity enhancement, agroecology, smallholder livelihoods, and policy integration have developed simultaneously. This expansion can lead to thematic fragmentation, making it difficult to identify dominant research clusters, emerging trends, and key contributors in the field. Without systematic mapping, stakeholders may struggle to assess how knowledge has evolved and which areas require further investigation. A comprehensive overview is therefore necessary to synthesize accumulated knowledge and guide future research directions.

Bibliometric analysis provides a systematic and quantitative approach to examine scientific literature within a defined research domain. By analyzing publication data, citation patterns, co authorship networks, and keyword co occurrence relationships, bibliometric methods enable the identification of structural connections and thematic clusters in scholarly communication. In the context of agroforestry research in tropical countries, bibliometric analysis can reveal patterns of publication growth, geographic distribution of research output, collaboration networks among countries and institutions, and shifts in research focus over time. Such analysis is valuable for understanding how agroforestry research has responded to global sustainability challenges between 2010 and 2024.

Although research on agroforestry in tropical countries has expanded significantly over the past decade, there is still limited comprehensive bibliometric analysis that systematically maps its development from 2010 to 2024. Existing studies often concentrate on specific themes or regions and do not provide an integrated overview of publication trends, collaboration structures, and thematic evolution across tropical countries as a whole. This lack of systematic mapping restricts the ability of researchers and policymakers to identify leading contributors, emerging topics, and knowledge

gaps within the field. Consequently, strategic research planning and evidence based policy formulation may not fully reflect the broader scientific landscape. Based on this gap, the objective of this study is to conduct a comprehensive bibliometric analysis of agroforestry research in tropical countries published between 2010 and 2024.

## 2. METHOD

This study employs a bibliometric research design to systematically map and analyze the development of agroforestry research in tropical countries published between 2010 and 2024. The data source used in this study is the Scopus database, selected due to its broad coverage of peer reviewed international journals and its comprehensive indexing of multidisciplinary research. The data retrieval process was conducted using a structured search strategy that combined relevant keywords such as "agroforestry" and terms associated with tropical contexts. The search was limited to publications within the 2010 to 2024 time frame and filtered to include articles, reviews, and conference papers written in English. After the initial extraction, the bibliographic data were exported in CSV format, including information such as authors, titles, abstracts, keywords, affiliations, publication years, citations, and references. A data cleaning process was then performed to remove duplicates and ensure consistency in author names and keyword variations before analysis.

To analyze and visualize the bibliometric structure, this study utilized VOSviewer software. VOSviewer was chosen because it is widely used in bibliometric studies and provides robust capabilities for constructing and visualizing bibliometric networks. Several types of analyses were conducted, including co authorship analysis to identify collaboration networks among authors, institutions, and countries, as well as keyword co occurrence analysis to detect thematic clusters and research hotspots. Citation analysis was also performed to determine the most influential publications and contributors in the field. The software applies a mapping technique based on network visualization, where nodes represent items such as authors or keywords and links represent relationships such as collaboration or co occurrence. The strength of relationships is measured through link strength values generated by the software.

In addition to network visualization, overlay and density visualizations were employed to explore temporal trends and research intensity. Overlay visualization was used to examine the evolution of research themes over time by assigning different colors to items based on average publication year. This allows the identification of emerging topics and shifting research priorities within agroforestry studies in tropical countries. Density visualization was used to highlight areas with high research concentration, indicating dominant themes or frequently studied topics.

## 3. RESULT AND DISCUSSION

### Co-Authorship Analysis

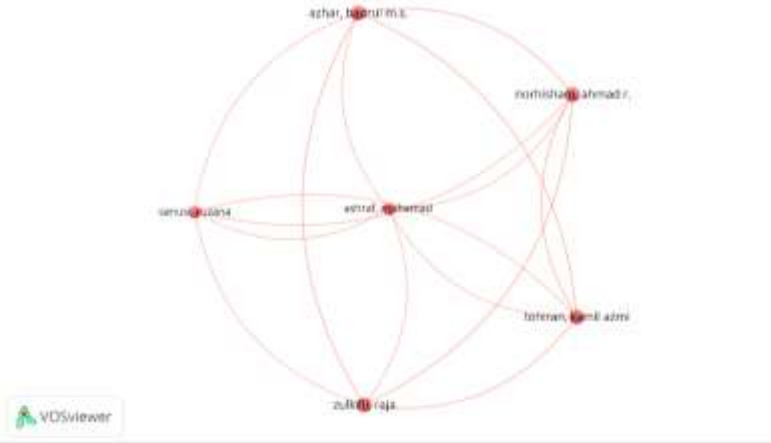


Figure 1. Author Visualization
Source: Data Analysis

Figure 1 illustrates a closely connected research cluster centered around Ashraf, Mohamad, who appears to act as the primary hub within this collaboration group. The network forms a single dominant cluster, indicating that these authors frequently collaborate within the same research circle rather than being dispersed across multiple independent teams. Strong linkages are visible between Ashraf, Mohamad and several co-authors such as Norhisham, Ahmad R., Tohiran, Kamil Azmi, Zulkifli, Raja, Sanusi, Suzana, and Azhar, Badrul M.S., suggesting repeated joint publications. The circular layout and dense interconnections imply a stable and possibly long-term collaborative structure, where knowledge production is concentrated within a relatively cohesive team. The absence of multiple clusters indicates limited fragmentation, meaning research output in this subset is driven by an integrated group rather than by competing or loosely connected sub-networks.

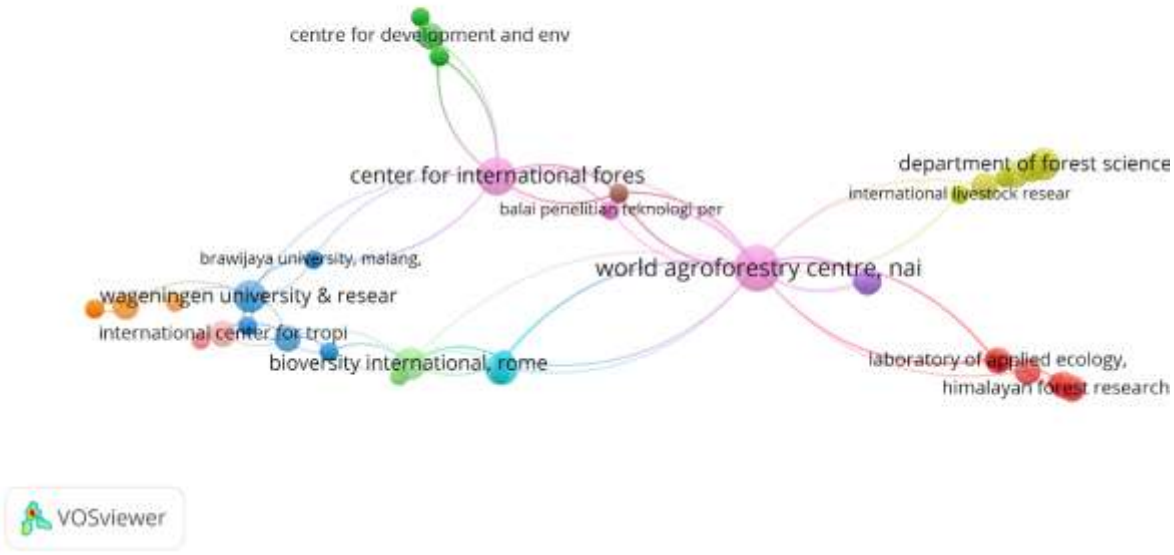


Figure 2. Institution Visualization
Source: Data Analysis

Figure 2 reveals that the World Agroforestry Centre (ICRAF) occupies a clear central and bridging position within the global agroforestry research landscape. It connects multiple institutional clusters, indicating its strategic role as a hub that links universities, research centers, and specialized laboratories across regions. On the left side of the network, European institutions such as Wageningen University & Research and other biodiversity-oriented centers form a cluster closely tied to academic and environmental research themes. In the lower-central part, institutions such as Biodiversity International (Rome) connect to ICRAF, suggesting collaboration in conservation, genetic resources, and sustainable land-use studies. Meanwhile, on the right side, forestry-focused institutions, including departments of forest science and applied ecology laboratories, form another cluster that links to ICRAF, reflecting integration between agroforestry and forest ecology research. The visualization indicates that agroforestry research in tropical countries is structured around internationally connected research hubs, with ICRAF acting as a key intermediary that facilitates cross-regional knowledge exchange and interdisciplinary collaboration.

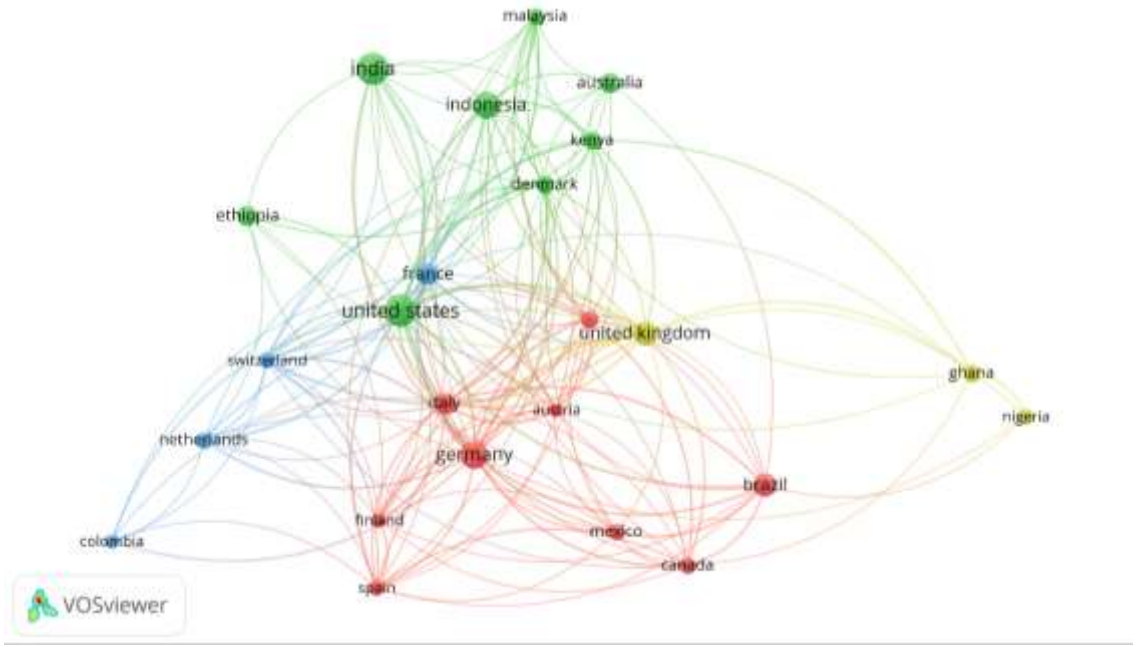


Figure 3. Country Visualization
Source: Data Analysis

Figure 3 shows a highly interconnected global structure in agroforestry research within tropical contexts, with the United States, United Kingdom, Germany, and India emerging as central nodes. The United States appears as a major hub linking European, Asian, and African countries, indicating strong international collaboration capacity. Germany and Italy form part of a dense European cluster that is closely connected to Latin American countries such as Brazil and Mexico, suggesting active transcontinental research partnerships. Meanwhile, India, Indonesia, Malaysia, Kenya, and Ethiopia represent a prominent tropical and Global South cluster, reflecting the geographical relevance of agroforestry studies in these regions. The United Kingdom also plays a bridging role, connecting African countries such as Ghana and Nigeria with European and American partners.

**Citation Analysis**

Table 1. Top Cited Literature

| Citations | Authors and Year | Title |
|---|---|---|
| 255 | [12] | Toward a whole-landscape approach for sustainable land use in the tropics |
| 250 | [13] | Change in tropical forest cover of Southeast Asia from 1990 to 2010 |
| 245 | [14] | What are the limits to oil palm expansion? |
| 168 | [15] | Agroecosystems and Primate Conservation in The Tropics: A Review |
| 151 | [16] | Climate Resilient Villages for Sustainable Food Security in Tropical India: Concept, Process, Technologies, Institutions, and Impacts |
| 142 | [17] | Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification |
| 132 | [18] | Global food security, biodiversity conservation and the future of agricultural intensification |
| 123 | [19] | Plant diversity, forest dependency, and alien plant invasions in tropical agricultural landscapes |
| 114 | [20] | Enhancing the sustainability of commodity supply chains in tropical forest and agricultural landscapes |
| 112 | [21] | The Future of Food: Domestication and Commercialization of Indigenous Food Crops in Africa over the Third Decade (2012–2021) |

Source: Scopus

**Keyword Co-Occurrence Analysis**

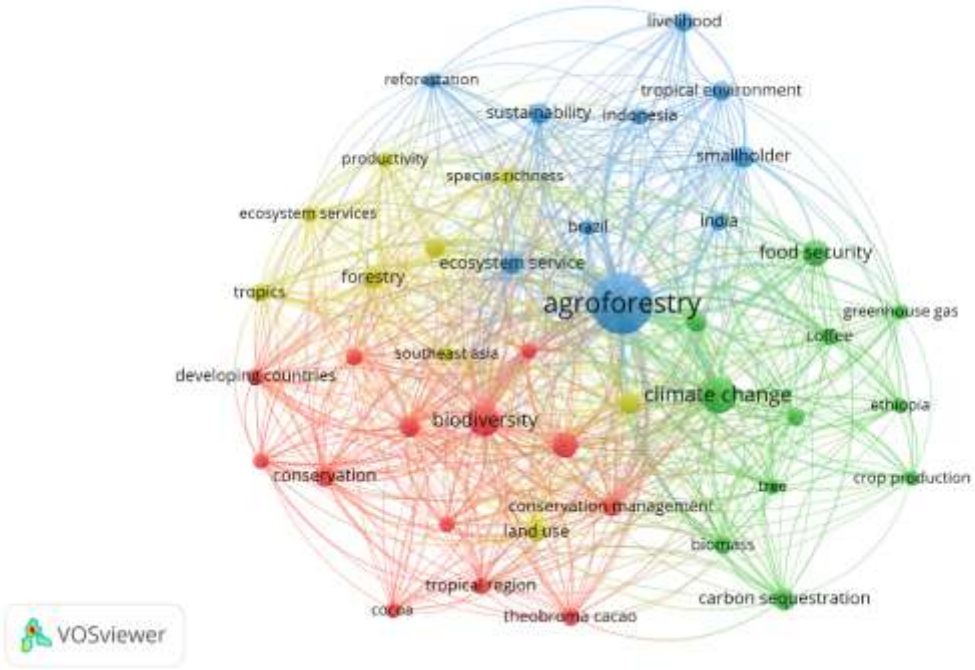


Figure 4. Network Visualization
Source: Data Analysis

Figure 4 illustrates that agroforestry functions as the central and most dominant theme within the research landscape, indicated by its largest node size and dense interconnections. The prominence of this keyword suggests that the literature consistently frames various environmental, socio-economic, and production-related issues within the broader agroforestry paradigm. Surrounding this core concept are highly connected themes such as climate change, biodiversity, and ecosystem service, reflecting the multidimensional nature of agroforestry research in tropical countries. The dense web of links indicates strong thematic integration rather than isolated research strands. One major cluster, highlighted in green, emphasizes climate-related and production-oriented themes. Keywords such as climate change, carbon sequestration, biomass, crop production, and greenhouse gas suggest that a significant portion of the literature focuses on agroforestry as a climate mitigation and adaptation strategy. This cluster reflects growing global attention to the role of tree-based farming systems in reducing emissions, enhancing carbon stocks, and supporting resilient agricultural production systems in tropical environments.

Another prominent cluster, shown in red, centers on biodiversity, conservation, land use, and tropical region, indicating strong ecological and conservation-oriented research. The frequent co-occurrence of biodiversity with conservation management and developing countries highlights the ecological importance of agroforestry landscapes in preserving species richness and habitat diversity, particularly in tropical regions facing deforestation pressures. The inclusion of commodity-specific terms such as cocoa and Theobroma cacao suggests that agroforestry systems linked to perennial crops are widely studied in biodiversity and conservation contexts. The blue cluster emphasizes socio-economic and sustainability dimensions, with keywords such as livelihood, smallholder, sustainability, tropical environment, and country-specific references like Indonesia and India. This indicates that agroforestry research increasingly integrates rural development and smallholder welfare into its analytical framework. The strong connections between sustainability and livelihood-related terms

suggest that agroforestry is not only examined for its ecological benefits but also for its capacity to enhance income stability, food security, and social resilience in tropical rural communities. The yellow cluster relates to productivity and ecosystem functions, including ecosystem services, productivity, forestry, and species richness. This reflects a bridging theme between ecological performance and agricultural output, highlighting the dual objective of agroforestry systems: maintaining ecological integrity while sustaining productive capacity.

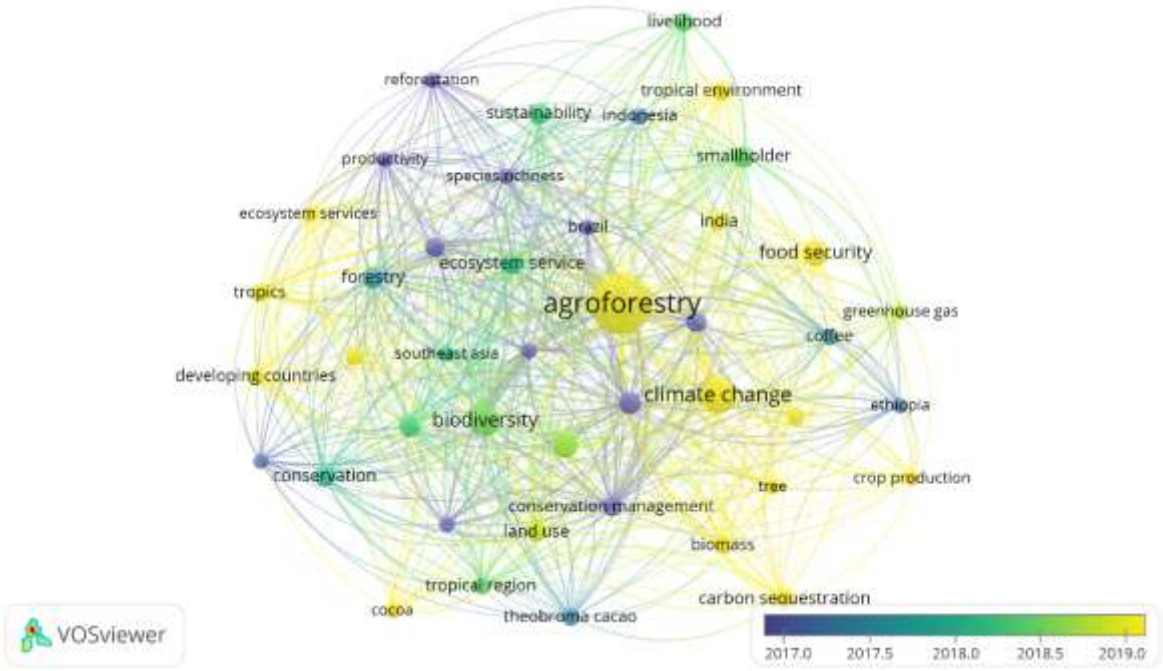


Figure 5. Overlay Visualization
Source: Data Analysis

Figure 5 reveals the temporal evolution of agroforestry research themes between 2010 and 2024. The color gradient, ranging from blue and green to yellow, indicates the average publication year of keywords. Core terms such as agroforestry appear in a more recent yellow shade, suggesting sustained and growing attention in the latter half of the period. Similarly, keywords like climate change, food security, carbon sequestration, and crop production are also highlighted in warmer tones, reflecting their increasing prominence in recent years. This indicates that contemporary agroforestry research in tropical countries is increasingly aligned with global sustainability and climate agendas. Earlier research themes, shown in cooler blue and green tones, include keywords such as conservation, reforestation, land use, and ecosystem service. These themes were foundational in earlier stages of the decade, focusing primarily on ecological restoration, biodiversity protection, and forest management within tropical landscapes. The presence of these terms in earlier years suggests that agroforestry research initially concentrated on environmental and conservation-based frameworks before gradually integrating broader sustainability concerns. The transition toward warmer-colored keywords such as livelihood, smallholder, food security, and climate-related terms reflects a shift toward more socio-ecological and policy-relevant research. This evolution suggests that recent studies increasingly emphasize the role of agroforestry in addressing global challenges such as climate mitigation, rural resilience, and sustainable food systems.

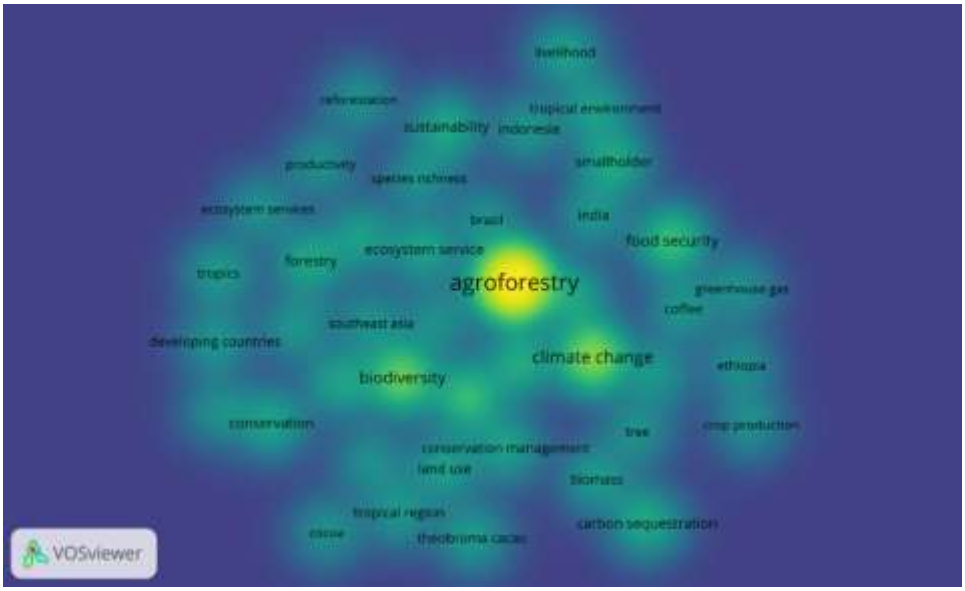


Figure 6. Density Visualization
Source: Data Analysis

Figure 6 highlights agroforestry as the most dominant and intensively researched theme, indicated by the brightest yellow concentration at the center of the map. Surrounding this core, high-density areas extend toward climate change, biodiversity, and ecosystem service, showing that these topics are frequently co-occurring and strongly embedded within the agroforestry discourse. The bright zones around these keywords suggest that the literature heavily emphasizes the ecological and climate-related dimensions of agroforestry in tropical countries, positioning it as both a conservation strategy and a climate mitigation mechanism. Moderate-density areas, shown in green, include themes such as food security, livelihood, smallholder, carbon sequestration, and crop production, reflecting significant but comparatively less concentrated research attention. Peripheral and lower-density terms such as cocoa, Theobroma cacao, and specific country references indicate more specialized or case-based studies within the broader framework.

**Discussion**

The bibliometric findings reveal that agroforestry research in tropical countries between 2010 and 2024 has evolved into a highly interconnected and interdisciplinary field. The dominance of the keyword agroforestry at the center of the co-occurrence and density maps confirms that the literature is not fragmented but instead organized around a cohesive conceptual core. This suggests that agroforestry is increasingly treated not merely as a land-use technique, but as a broader sustainability framework integrating ecological restoration, climate mitigation, rural livelihoods, and food systems transformation. The strong thematic integration indicates that scholars are approaching agroforestry through holistic perspectives rather than isolated disciplinary lenses. One of the most significant patterns identified is the strong emphasis on climate-related themes. Keywords such as climate change, carbon sequestration, biomass, and greenhouse gas have become increasingly prominent, particularly in more recent years as shown in the overlay visualization. This trend reflects the alignment of agroforestry research with global climate agendas, including carbon neutrality, nature-based solutions, and climate-resilient agriculture. Tropical agroforestry systems are frequently positioned as effective mechanisms for carbon storage while maintaining productive agricultural landscapes. This shift suggests that agroforestry research is now strongly embedded within global environmental governance and climate policy discourses.

At the same time, biodiversity and conservation remain foundational pillars within the research landscape. The clustering

of keywords such as biodiversity, conservation, species richness, and land use highlights the ecological importance of agroforestry systems in tropical regions facing deforestation and habitat degradation. The presence of commodity-specific terms such as cocoa and coffee further indicates that biodiversity conservation is often studied within agroforestry commodity systems, particularly shaded perennial crops. This reinforces the understanding that tropical agroforestry plays a dual role: sustaining agricultural production while maintaining ecological integrity. Another important evolution in the literature is the growing integration of socio-economic dimensions. The prominence of terms such as livelihood, smallholder, and food security indicates that agroforestry research increasingly acknowledges rural welfare and social resilience as central concerns. The overlay analysis suggests that these themes have gained stronger attention in recent years, reflecting a shift toward people-centered sustainability. In tropical countries where smallholder farmers dominate agricultural landscapes, agroforestry is studied not only for ecological benefits but also for its capacity to stabilize income, diversify risk, and enhance long-term food security.

The country collaboration network further reveals a globalized research structure characterized by strong North–South and South–South partnerships. Countries such as the United States, United Kingdom, and Germany function as major hubs, often connecting tropical nations including India, Indonesia, Kenya, Brazil, and Ethiopia. This pattern suggests that while developed countries maintain high research productivity and centrality, tropical countries are increasingly active contributors rather than passive study sites. However, the network also indicates that research influence remains concentrated within a limited number of institutions and countries, pointing to potential imbalances in knowledge production and leadership. Institutional collaboration patterns highlight the strategic role of international research centers, particularly the World Agroforestry Centre, in bridging multiple regional clusters. Such institutions facilitate interdisciplinary and cross-country cooperation, reinforcing the global visibility of agroforestry research. Their central position suggests that global research agendas may significantly shape thematic priorities in tropical contexts. This centralization can be beneficial for coordination but may also risk marginalizing locally driven research agendas if not balanced with stronger national research leadership.

The temporal evolution of keywords demonstrates a clear transition in research emphasis. Earlier years were dominated by conservation and ecosystem-based approaches, while more recent years emphasize climate resilience, carbon dynamics, and food security. This trajectory reflects the broader shift in sustainability science from conservation-focused paradigms toward integrated socio-ecological systems thinking. The convergence of climate, biodiversity, and livelihood themes indicates that agroforestry is increasingly conceptualized as a multifunctional system capable of delivering multiple ecosystem services simultaneously. Despite the strong thematic integration, the density map suggests that certain areas remain comparatively less developed. Topics related to governance mechanisms, policy instruments, market integration, gender dimensions, and financial incentives appear less dominant within the visual network. Given the importance of land tenure security, institutional frameworks, and value chain access in tropical agroforestry adoption, future research may benefit from strengthening these socio-institutional dimensions. Additionally, while tropical regions are central to agroforestry practice, research production is still influenced by institutions in the Global North, suggesting opportunities to expand locally led scholarship.

## 4. CONCLUSION

This bibliometric analysis demonstrates that agroforestry research in tropical countries during 2010–2024 has

developed into a highly interconnected and multidisciplinary field, strongly centered on climate change mitigation, biodiversity conservation, ecosystem services, and smallholder livelihoods. The findings reveal a clear temporal shift from conservation-oriented studies toward more integrated socio-ecological and climate-responsive themes, reflecting the growing alignment of agroforestry with global sustainability agendas. International collaboration networks are robust, with major research hubs bridging partnerships between developed and tropical countries, although knowledge production remains concentrated within certain institutions.

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