



Climate Vulnerability and Sustainable Livelihood Strategies in Agriculture: A Bibliometric Analysis

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HIGHLIGHT

- Publications on Climate Vulnerability and Sustainable Livelihood rose sharply from 2020 and reached the highest level in 2025.
- Livelihood, vulnerability, agriculture and food security formed the core keyword network.
- Recent trends shifted towards adaptation, resilience and livelihood diversification.

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ABSTRACT

Rural households are increasingly vulnerable to climate-induced risks by impacting livelihoods, income, food security, access to resources and adaptive capacity. Livelihood capitals and sustainable livelihood strategies for climate vulnerability were reviewed and mapped through bibliometric analysis. Scopus-indexed journal articles published during 2017-2026 were analysed following PRISMA-based screening. Biblioshiny and VOSviewer were used to examine annual scientific production, major sources, keyword co-occurrence, thematic mapping, trend topics and conceptual structure. The findings show a steady increase in research output after 2020, with sustainability, development, climate change and disaster-risk journals contributing prominently. Keyword and thematic analyses revealed that livelihood, vulnerability, agriculture, food security, adaptation and resilience form the core knowledge structure of the field. Recent trends indicate a shift from descriptive vulnerability assessment towards solution-oriented themes such as adaptive capacity, livelihood diversification and climate-smart agriculture. However, livestock systems, gender dimensions, local institutions and extension advisory mechanisms remain weakly integrated. The study concludes that agricultural extension must move beyond crop-centred advisory services towards livelihood-based, climate-resilient extension models that emphasise vulnerability diagnosis, diversification support, institutional convergence, climate information services, and capacity building.

INTRODUCTION

Climate variability has emerged as one of the most important threats to rural livelihood security, especially in developing countries, where agriculture and other natural resource based

livelihood activities continue to be the key sources of income, employment, and food security. Climate risks are not the same for all rural households, however. Vulnerability is a function of agro-ecological conditions, livelihood dependence, access to productive resources, institutional support and adaptive capacity (Morton,

2007). Belay and Lebeza (2024) showed that livelihood vulnerability varies across different agro-ecological zones in north-western Ethiopia, indicating the need to understand the local production environment and household resource endowment to understand climate risk. Tribal, marginal, and smallholder farming households with livelihoods in climate-sensitive sectors are particularly vulnerable in India. Kumar and Mohanasundari (2025) noted significant geographical disparities in the climate vulnerability of tribal households in Central India; similarly, Hazarika et al. (2024) highlighted the roles of exposure to climatic shocks, socio-economic sensitivity, and the limited adaptive capacity of rural households. The vulnerability to climate change is not limited to environmental impacts and is a multidimensional problem in terms of livelihoods, institutional frameworks, and rural development.

The Sustainable Livelihood Framework (SLF) offers a comprehensive perspective on this relationship by describing how households are resilient in their livelihoods and across five livelihood capitals: human, social, natural, physical, and financial. These capitals affect how households diversify income sources, use agriculture strategies in the face of climate change, access finance, build social connections, and withstand climate-related shocks and stress. Natarajan et al. (2022) pointed out that SLF still has much relevance for current development research but needs to be resituated in the context of the new risks, social inequalities and environmental shifts. The dimensions of climate vulnerability, exposure, sensitivity, and adaptive capacity are commonly used to assess climate vulnerability. Hahn et al. (2009) developed the Livelihood Vulnerability Index (LVI) and LVI-IPCC to measure these three aspects, and Opiyo et al. (2024) demonstrated that households with high exposure and low adaptive capacity had significantly higher vulnerability.

While studies on climate change adaptation, resilience, livelihood diversification, and sustainable agriculture have grown significantly, the literature remains scattered across agricultural sciences, environmental studies, rural development, disaster risk reduction, and sustainable agriculture. Bibliometric analysis is a useful tool for summarising the vast body of knowledge that has accumulated over the years and for identifying the most influential authors, emerging topics, collaborations, and research gaps (Donthu et al., 2021; Chandra et al., 2026). Previous bibliometric research has largely focused on climate change, agricultural sustainability, or adaptation, without paying much attention to the interdependent linkages among livelihoods, vulnerability, and agriculture. Thus, the present study offers a thorough bibliometric analysis to capture the intellectual landscape and development of livelihood, vulnerability and agriculture research.

METHODOLOGY

The research was conducted through a systematic literature review and a bibliometric analysis of the literature on climate vulnerability and livelihood capitals/sustainable livelihood strategies. The review was carried out in a transparent and systematic way, following the PRISMA 2020 guidelines for identifying, screening and selecting relevant studies (Page et al., 2021). Science-mapping techniques were employed for bibliometric analysis to explore

publication trends, influential publications, collaboration trends, thematic evolution, and research gaps (Donthu et al., 2021).

Scopus was chosen because it offers extensive coverage of high-quality, peer-reviewed literature across agriculture, environmental sciences, social sciences, and development studies. The search was conducted in English, for journal articles from 2017 to 2026 with a query of TITLE-ABS-KEY (Livelihood) AND TITLE-ABS-KEY (Vulnerability) AND TITLE-ABS-KEY (Agriculture). To ensure consistency and quality, conference papers, book chapters, reviews, editorials, and notes were not included. There were 1,449 records found. Following the deduplication and screening of titles, abstracts and metadata for theme relevance, 1,094 articles were retained for analysis. Selected records were exported in CSV format, including bibliographic data, such as author, title, abstract, keywords, source title, volume, year, affiliation and number of citations. Synonymous and closely related terms were standardised before performing co-occurrence analysis to ensure the accuracy of the co-occurrence analysis.

The Bibliometrix package (version 4.3.2) via the Biblioshiny interface and the VOSviewer (version 1.6.20) were used for bibliometric analyses. The annual production of scientific items has been analysed, the main journals, authors, institutions, countries, citation performance, as well as the thematic evolution, conceptual structure and collaboration networks have been determined (Aria & Cuccurullo, 2017). Keyword co-occurrence networks and thematic clusters were visualised using VOSviewer (Van Eck & Waltman, 2010). The results of the bibliometric analysis were analysed using the Sustainable Livelihood Framework, connecting themes that emerged with livelihood capital, climate vulnerability dimensions, and sustainable livelihood strategies, thereby highlighting research gaps and a pathway for future research on climate change and rural development.

RESULTS

Scopus was selected due to its wide range of high-quality, peer-reviewed literature across the fields of agriculture, environmental sciences, social sciences, and development studies. The search was done in English using the terms TITLE-ABS-KEY (Livelihood) AND TITLE-ABS-KEY (Vulnerability) AND TITLE-ABS-KEY (Agriculture) for journal articles published between 2017 and 2026. To maintain uniformity and quality, conference papers, book chapters, reviews, editorials, and notes were omitted. A total of 1449 records were found. After deduplication and screening of titles, abstracts, and metadata for theme relevance, 1,094 articles were retained for analysis. Selected records were exported as a CSV file comprising bibliographic information (author, title, abstract, keywords, source title, volume, year, affiliation and number of citations). Synonymous and closely related terms were standardised before performing co-occurrence analysis to ensure the accuracy of the co-occurrence analysis.

The PRISMA flow diagram (Figure 1) summarises the study selection process for this review. A total of 1,449 records from the Scopus database have been identified during the period from 2017 to 2026. 1,307 records were screened after duplicate records were removed, and a further examination excluded 113 non-relevant publications, such as book chapters, conference papers, and short

communications. Thereafter, 1,194 reports were evaluated, and 32 reports were found in non-English languages and 68 were articles that were not open access. Last, a critical literature selection procedure was followed and 1,094 studies were included in the bibliometric analysis.

Annual scientific production

The annual scientific production showed a gradual increase in publications on livelihood capitals, climate vulnerability, and livelihood strategies during 2017–2025 (Figure 2). The publication output was moderate during 2017–2019, followed by a noticeable increase from 2020 onwards. The number of publications further increased during 2021–2023, reaching its highest level in 2025, with approximately 140 publications. This signals the growing focus on climate vulnerability, livelihood resilience, adaptation and sustainable rural livelihood systems. The drop in 2026 should be viewed with caution as the data for this year was not fully available.

Most relevant sources

The source analysis identified the key journals published in this field (Figure 3). The top journal was Sustainability (Switzerland)

followed by Environment, Development and Sustainability, Climatic Change, Regional Environmental Change and Climate and Development. The other substantial sources were Geo Journal, PLOS ONE, International Journal of Disaster Risk Reduction, Land Use Policy and Agricultural Systems. The spread of publications across these journals suggests that research on climate vulnerability and livelihood is multifaceted, focusing on sustainability science, development studies, environmental change, disaster risk reduction, land-use systems and agricultural resilience.

Keyword co-occurrence network

The co-occurrence analysis of keywords showed the main thematic connections in these publications (Figure 4). The keywords that stood out were livelihood, vulnerability, and agriculture and food security, suggesting that these are the key themes of the research area. There were four major clusters. The first cluster was related to livelihood, smallholders, food security and coping mechanisms. The second cluster related to agriculture, ecosystems, climate and land use. The third cluster pertained to drought, disasters, adaptation strategies and India, emphasising the need for hazard and region-specific studies. The fourth was associated with

Figure 1. PRISMA flow chat

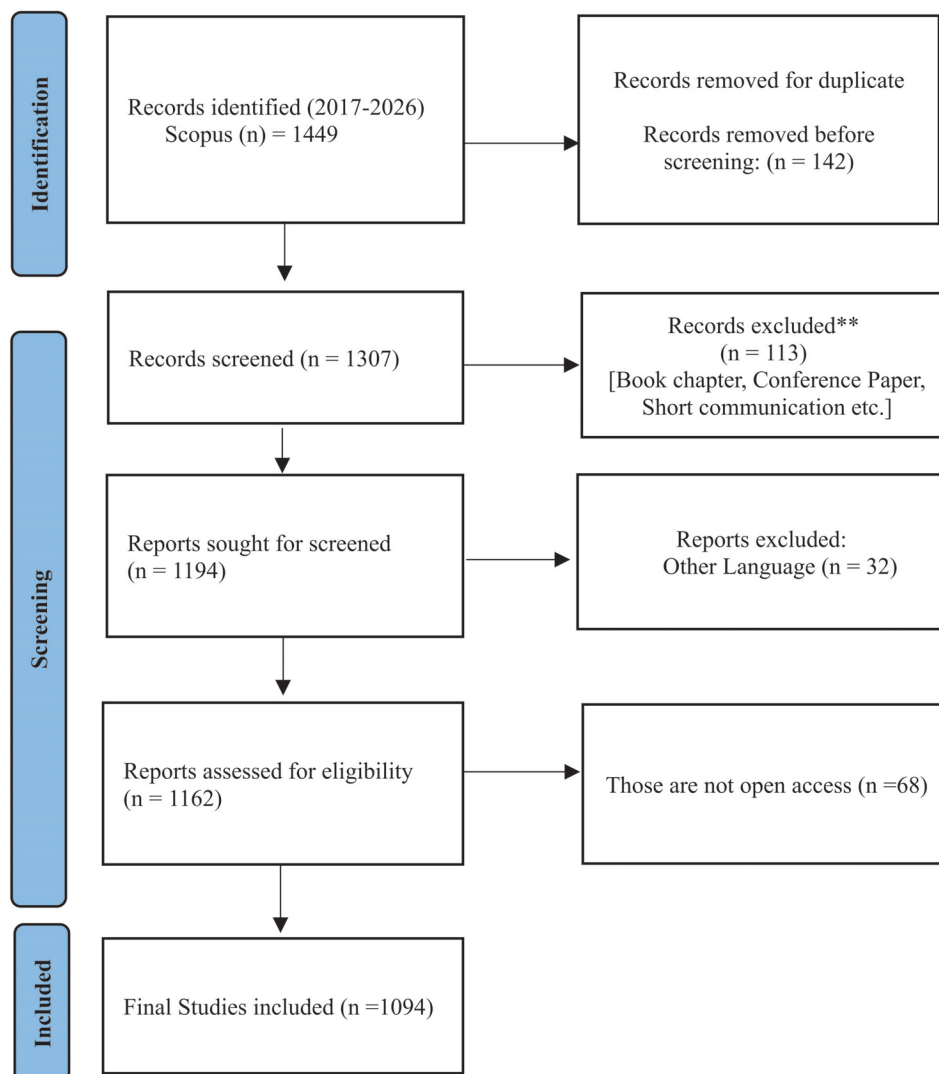


Figure 2. Annual scientific production

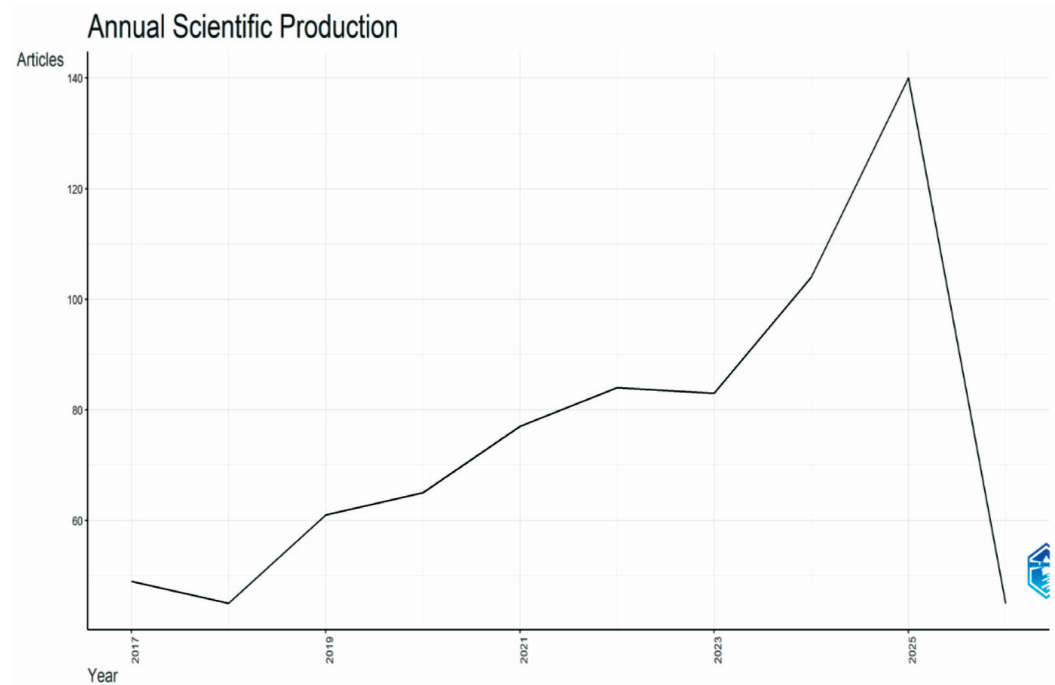
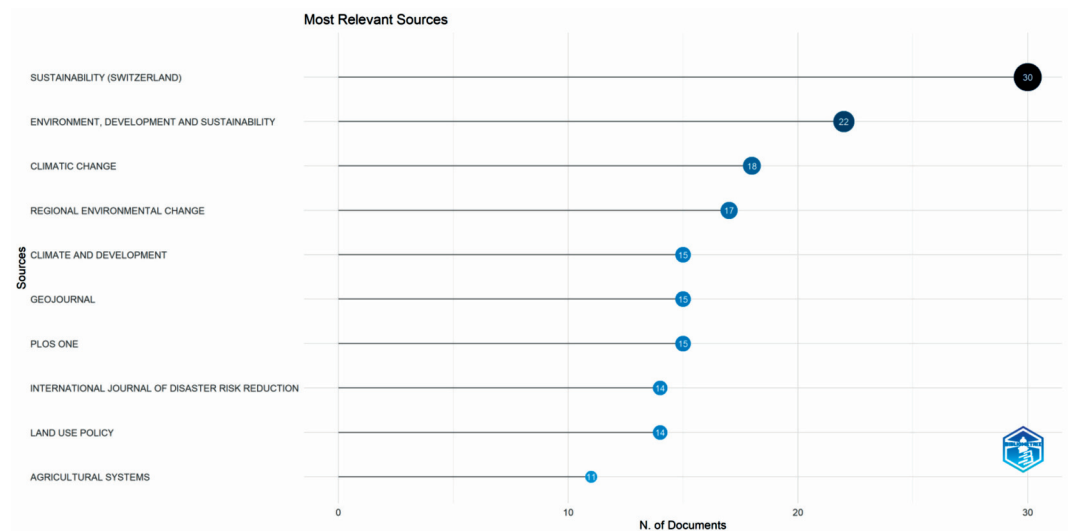


Figure 3. Most relevant source



farmers, households, humans, and income. The inclusion of concepts such as exposure, sensitivity, and adaptive capacity suggests that the literature is heavily influenced by existing climate vulnerability assessment literature.

Thematic map

The thematic map categorised research themes into centrality and density (Figure 5). Vulnerability, climate change and livelihoods were significant themes, highlighting their prominence. These themes were highly relevant but immature in their own development. Agriculture, human and article appeared as motor themes, suggesting that they were highly developed and well connected with other themes. Sustainability, sustainable development, and economics appeared as niche themes, indicating they were relatively mature but probably less well connected to other themes. Risk assessment, decision-making, and Bangladesh were present in the emerging or

declining quadrant, suggesting that these topics might be worth exploring, particularly in studies of site-specific and decision-support research.

Trend topics

The trend topic analysis revealed a gradual shift in research from vulnerability assessment to adaptation- and resilience-focused themes (Figure 6). Terms such as vulnerability, climate change and livelihood were consistent over the years and demonstrated their ongoing relevance. Recently, the keywords climate adaptation, livelihood resilience, livelihood diversification, and adaptive capacity have become more prominent. This suggests a research focus on finding solutions. Middle period themes like drought, agricultural production and risk assessment were more prevalent, whereas recent trends show a growing focus on sustainable development, resilience and climate responsive livelihoods.

Figure 4. Co-occurrence with index keywords

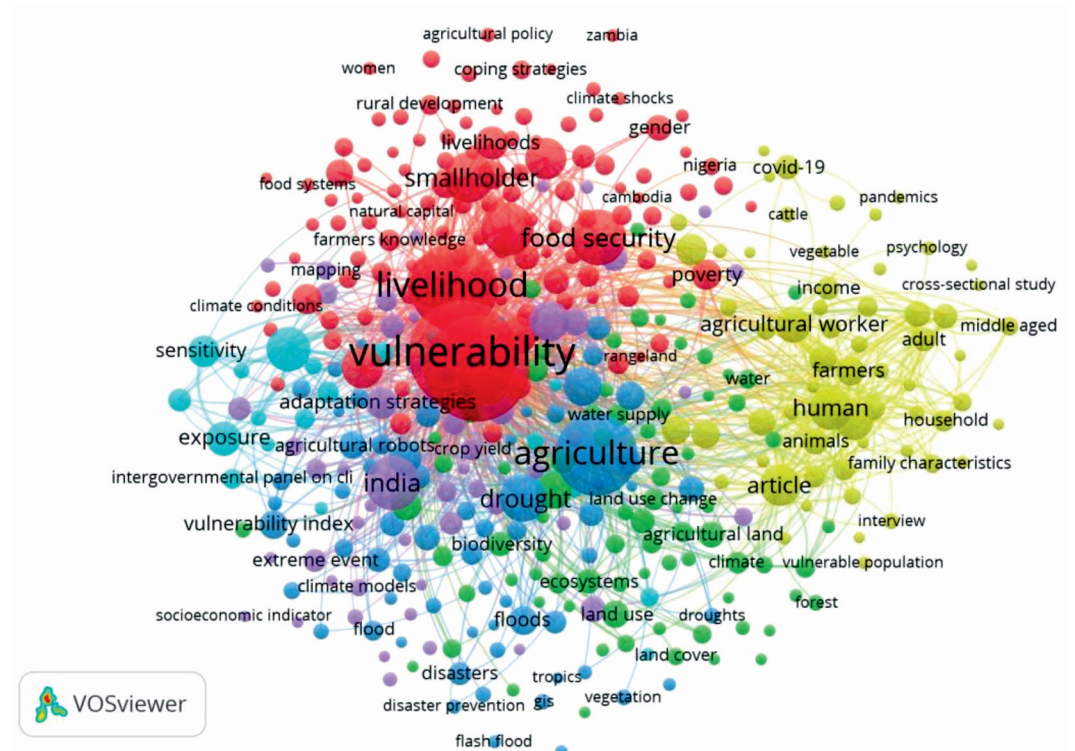
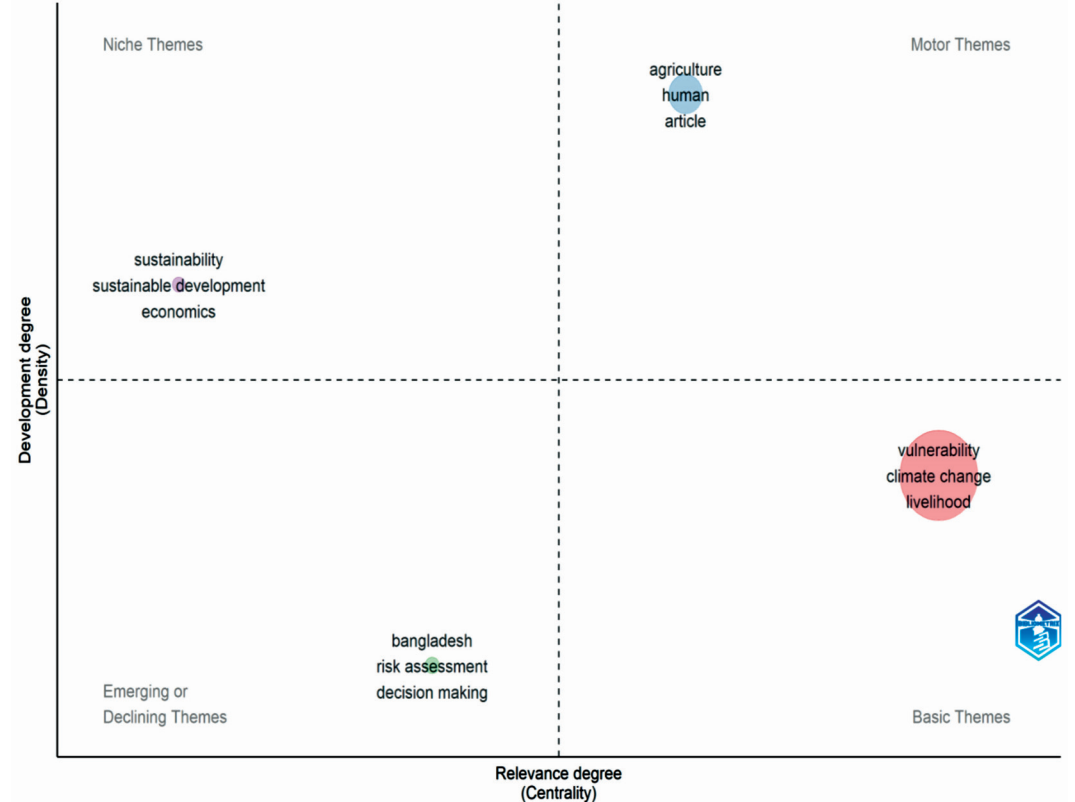


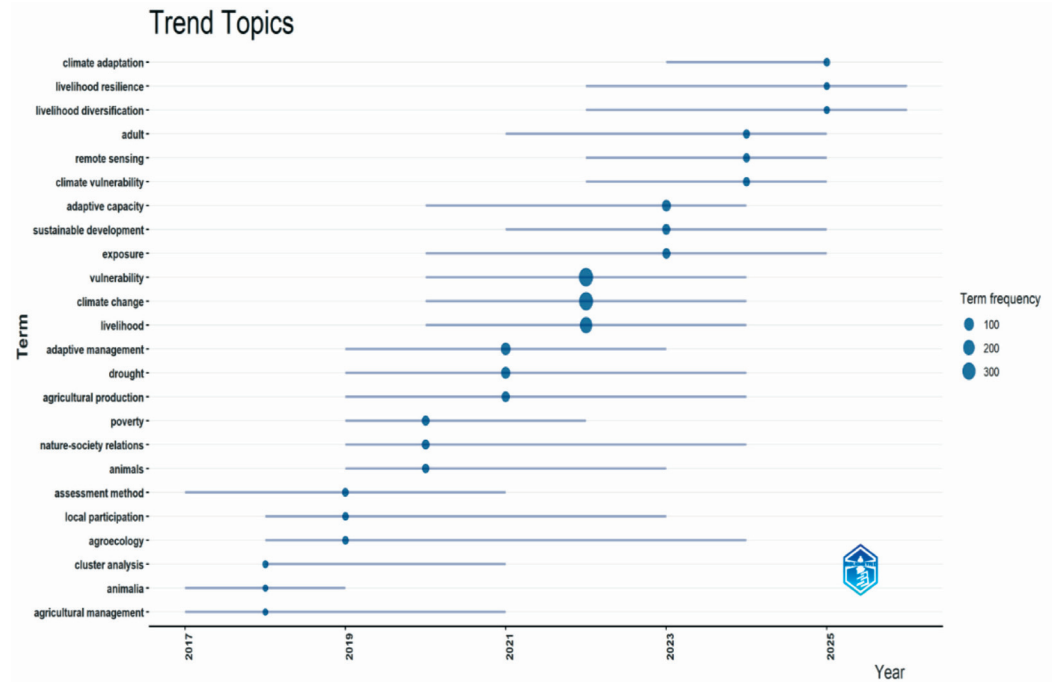
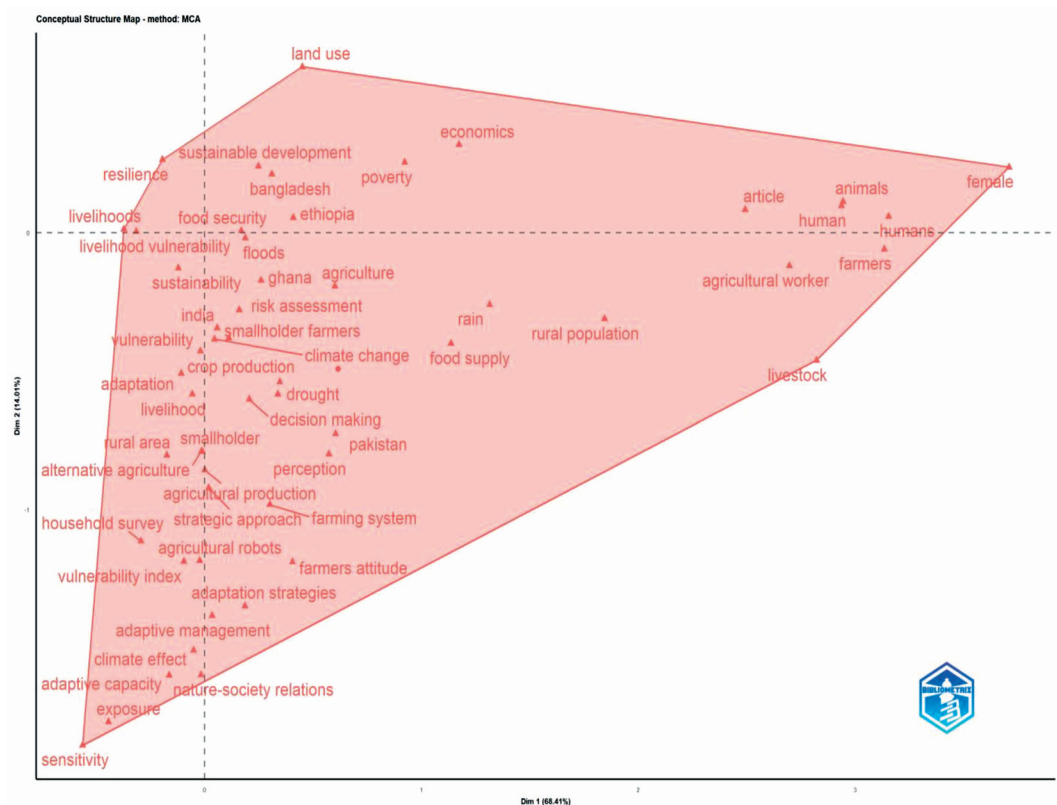
Figure 5. Thematic map



Factorial map

The factorial map obtained from the Multiple Correspondence Analysis illustrated the conceptual organisation of the research topic (Figure 7). The central cluster of terms (climate change, agriculture, smallholder farmers, food security, and risk assessment) was close

to the centre of the map, suggesting a high degree of conceptual inter-relationship. Vulnerability, resilience, adaptation, adaptive capacity and livelihoods were also grouped together, revealing the link between climate risk and livelihoods. Geographical markets such as India, Bangladesh, Ethiopia, and Ghana highlighted the significance of

Figure 6. Trend topics**Figure 7.** Factorial map

developing country settings in this research field. Outlier themes, including livestock, farmers, and animals, were relatively separate from the core theme, indicating that research on these topics is not as well connected within the field of livelihood vulnerability.

DISCUSSION

Livelihood capitals and climate vulnerability have evolved from descriptive vulnerability studies towards resilience and solution-

oriented studies. This is important for extension because vulnerability to climate change is no longer just a crop production risk issue; it's a livelihood systems issue. The keywords "livelihood", "vulnerability", "agriculture" and "food security" in the network indicate that extension strategies should be framed around households' livelihood portfolios rather than agricultural production. This aligns with the Sustainable Livelihood Framework, which posits that human, social, natural, physical, and financial

capitals drive rural households' responses to shocks (Natarajan et al., 2022; Roy et al., 2025).

The rising trend in publications since 2020 reflects the increased research and policy focus on climate-resilient livelihoods. The challenge with this increase is not only the number of publications, but also how they are translated into field-level advisory approaches. The approach of extension is still technology transfer focused, with climate vulnerability needing diagnostic, participatory and site-specific advisory models. Mallappa and Gadde (2025) developed a tool to measure livelihood vulnerability of climate-sensitive farming communities, reinforcing the need for extension agencies to use locally valid vulnerability indicators before recommending interventions.

The co-occurrence of agriculture, food security, smallholders, coping strategies, and adaptive capacity indicates that vulnerability is closely linked to farmers' ability to reorganise their livelihood choices. Therefore, adaptation should not be treated as a single practice, such as the introduction of drought-tolerant varieties or irrigation improvements. Rather, it should be framed as a bundle of decisions involving crop choice, income diversification, credit access, risk information, insurance, collective action and institutional linkage. Evidence from Bundelkhand showed that farmers' adaptation behaviour was influenced by access to institutional credit, weather information, and crop insurance, indicating that adaptation depends strongly on enabling services rather than farmer awareness alone (Jatav & Singh, 2023). Shitu and Nain (2025) suggested that agencies and stakeholders assisting farmers in scaling up the adoption of climate smart agricultural practices, like precision conservation agriculture, should develop a shared understanding and strategy for promoting these cutting-edge technologies within farming communities.

The emergence of livelihood diversification and livelihood resilience as recent trend topics is particularly relevant for extension science. Diversification reduces livelihood sensitivity by spreading risk across farm, off-farm and non-farm activities. Pal et al (2017) recommended to diversify their activities to reduce the livelihood vulnerability in this age of climate change. In Odisha, occupational diversification among farmers was influenced by education, non-farm engagement, achievement motivation and management orientation, explaining substantial variation in diversification behaviour (Jayasingh & Mishra, 2024). Extension services should include training in entrepreneurship, skills, market information, and enterprise facilitation, not just crop advisory.

The thematic map also reveals that sustainability and economics are relatively mature but less connected with the mainstream vulnerability literature. This is a gap because farmers judge adaptation based on ecological and non-ecological value, including cost, labour, profit, risk and social acceptability. Climate-smart agriculture studies also support this argument (Mishra et al., 2024). Mishra et al. (2025) observed that improving farmers' knowledge and economic capacity could strengthen adoption of climate-smart agricultural practices, suggesting that technical recommendations require strong extension mediation for adoption among vulnerable smallholders.

The factorial map indicates that livestock, animals and farmers remain relatively peripheral in the broader livelihood vulnerability

literature. This is a concern because livestock often functions as a buffer asset during climate and income shocks, especially for smallholders and rainfed farmers (Verma et al., 2025). Similarly, the limited visibility of gender, local institutions and extension advisory systems points to a conceptual gap. Climate vulnerability is experienced differently across gender, caste, resource ownership and institutional access, and ignoring these differences can make adaptation programmes technically sound but socially ineffective (Pundir et al., 2025). This requires vulnerability diagnosis, capital-specific interventions, farmer collectives, institutional convergence, digital climate services, local adaptation planning and continuous feedback-based extension (Lalu et al., 2025; Saha et al., 2026). The bibliometric study signals the need for a new extension architecture that can strengthen adaptive capacity and sustainable livelihood resilience in the face of climate vulnerability.

CONCLUSION

The study reveals a clear shift in research from vulnerability assessment towards resilience-oriented and livelihood-focused approaches, with strong emphasis on livelihood capitals, adaptation and diversification. The findings highlight that vulnerability is not solely determined by climate exposure but by the strength of human, social, financial, physical and natural capitals. The growing prominence of livelihood diversification, adaptive capacity and climate-smart practices indicates a transition towards solution-driven research; however, gaps remain in integrating livestock systems, gender dimensions and local institutional mechanisms. The study implies the need to move beyond production-centric advisory towards livelihood-based extension models. Extension systems should prioritise vulnerability assessment, diversification support, climate information services, institutional linkage and capacity building. Strengthening farmer collectives, promoting rural enterprises and integrating crop-livestock systems will be critical for enhancing adaptive capacity and ensuring sustainable, climate-resilient rural livelihoods.

DECLARATIONS

Ethical consideration and consent to participate: The study was conducted through the Bibliometrix package (version 4.3.2) via the Biblioshiny interface and the VOSviewer (version 1.6.20) for bibliometric analyses of the data fetched from Scopus database. Hence, ethical issues were not involved.

Conflict of interest: The authors reported that there were no known competing financial interest and personal relationships to disclose that could have appeared to influence the work reported in this paper.

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