Empowering climate action through policy analysis and education in Gilgit-Baltistan: a comprehensive mixed method analysis

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Introduction: The study addresses the critical gap in climate policy implementation and public education in Gilgit-Baltistan, a region highly vulnerable to climate change but underrepresented in research and policy discourse. While national climate policies exist, their translation into localized action remains ineffective due to logistical, financial, and institutional barriers.

Methods: This research aims to bridge this gap by conducting a comprehensive mixed-method analysis to assess policy shortcomings and develop targeted educational interventions. The methodology follows a four-phase approach: first, a bibliometric analysis of over 100 peer-reviewed articles and policy documents identifies research trends, gaps, and key contributors. Second, semi-structured interviews with various stakeholders, including community leaders, religious scholars, and local policymakers, reveal educational needs and awareness levels regarding climate change. The third phase involves the documentation of environmental awareness initiatives at the University of Baltistan, providing empirical evidence on existing efforts. Finally, using a Design-Based Research strategy, an educational course tailored to the socio-cultural context of Gilgit-Baltistan is developed and evaluated.

Results: Findings highlight a severe lack of interdisciplinary collaboration in Pakistan's climate research, with Gilgit-Baltistan often overlooked in national studies. Public awareness, particularly among youth and religious leaders, is insufficient, necessitating educational programs that integrate local knowledge and practical climate action strategies. Additionally, weak policy implementation in remote regions due to governance constraints underscores the need for multi-sectoral collaboration and sustainable financial support.

Conclusion: The study concludes that empowering local communities through targeted education and inclusive policymaking is essential for fostering climate resilience in Gilgit-Baltistan. It calls for urgent policy adaptation, stakeholder engagement, and structured climate education programs to ensure sustainable environmental stewardship in the region.

KEYWORDS

bibliometric analysis, empowering climate action, education, policy analysis, semi-structure interviews

Introduction

Education is a critical tool for fostering a culture of climate awareness and action (Ahmed et al., 2023). Educating communities about the causes and consequences of climate change and equipping them with the necessary knowledge and skills to adapt can generate grassroots support for climate initiatives (Asif et al., 2024). Empowering climate action in Gilgit-Baltistan requires collaboration among various stakeholders, including government agencies, non-governmental organizations, academic institutions, and local communities (Gillani et al., 2022). By fostering partnerships and encouraging multi-stakeholder dialogue, resources can be leveraged, knowledge shared, and efforts coordinated for maximum impact (Ergun et al., 2021).

Several studies have highlighted the alarming rate of glacial melt in Gilgit-Baltistan, driven by rising temperatures and changing precipitation patterns. For instance, studies by Ahmed and Luqman (2024) and Davis et al. (2021) have documented significant glacial retreat and its implications for water resources, agriculture, and disaster risk in the region. Additionally, research by Ali et al. (2022) has emphasized the increased frequency of natural disasters, such as landslides and flash floods, exacerbated by climate change. The role of policy analysis in formulating effective climate adaptation strategies has been recognized in various studies. Khan et al. (2022b) have stressed the importance of integrating scientific research into policy-making to develop targeted interventions for climate resilience. However, there is a noticeable gap in the literature regarding the implementation and evaluation of these policies at the local level in Gilgit-Baltistan (Khan et al., 2024). Most studies focus on high-level policy recommendations without examining their practical application and impact on the ground (Masud and Khan, 2024). In conclusion, empowering climate action in Gilgit-Baltistan through policy analysis and education is vital for safeguarding the region's environment and enhancing the resilience of its communities. By leveraging informed decision-making and community engagement, the challenges posed by climate change can be addressed, creating a sustainable future for Gilgit-Baltistan (Kousar et al., 2022).

Climate change presents substantial risks to the distinctive ecological and socio-economic framework of Gilgit-Baltistan (Afzal et al., 2023). This region, characterized by its mountainous terrain and vulnerable ecosystems, faces significant challenges such as glacial melt, erratic weather patterns, and biodiversity loss (Bano et al., 2021). The research underscores the significance of education and community engagement in fostering climate resilience. Studies by Hoodbhoy et al. (2023) and Ali (2021) have shown that raising awareness and building local capacity through education can empower communities to adopt sustainable practices and participate in climate action. Despite these findings, there is limited research on the specific educational strategies that are most effective in the context of Gilgit-Baltistan. Moreover, the role of indigenous knowledge and how it can be integrated into educational programs remains underexplored (Mafi-Gholami et al., 2021).

Effective climate action in Gilgit-Baltistan necessitates a comprehensive approach that integrates robust policy analysis with community education and engagement (McMahon and Gray, 2021). Effective climate action begins with thoroughly understanding the region's unique environmental dynamics and vulnerabilities (Hasan and Kouser, 2023). Policy analysis plays a crucial role in identifying the key factors contributing to climate change and its impacts on Gilgit-Baltistan (Mujtaba et al., 2024). Through in-depth research and data analysis, policymakers can develop tailored strategies that address the specific needs and challenges of the region. Policy analysis facilitates the identification of the most vulnerable areas and communities in Gilgit-Baltistan (Mustafa et al., 2023). This involves assessing risk factors associated with glacial melt, soil erosion, and changes in precipitation patterns, thereby enabling targeted interventions (Haq and Shafi, 2022).

While existing research provides a strong foundation for understanding the climate challenges in Gilgit-Baltistan, several gaps remain. There is a need for studies that evaluate the effectiveness of climate policies implemented in Gilgit-Baltistan, assessing their impact on local communities and ecosystems (Nadeem and Nawaz, 2023). More research is required to identify and develop educational strategies tailored to the cultural and socio-economic context of Gilgit-Baltistan. This includes integrating indigenous knowledge with modern scientific understanding (Nawaz et al., 2022). In conclusion, while significant progress has been made in understanding the climate challenges facing Gilgit-Baltistan, addressing these challenges effectively requires a more nuanced approach that combines robust policy analysis with targeted educational initiatives. That is why this research's first phase was to perform a bibliometric analysis of at least 100 peer-reviewed articles and policy documents, resulting in a comprehensive report detailing publication trends, key research themes, and gaps. A detailed report and a peer-reviewed journal article summarizing the trends, key research themes, influential works, and gaps in the existing literature on climate policies and education in Gilgit-Baltistan. This report will serve as a foundational reference for future research and policy-making, helping to identify areas that require further investigation and providing a roadmap for developing more effective climate policies.

So, the objectives of this project were to:

1. Analyze the literature on climate policies and education in Gilgit-Baltistan to identify research trends, gaps, and influential works.
2. Measure the level of climate change awareness and educational needs among local communities.
3. Design an educational course tailored to the local context of Gilgit-Baltistan and evaluate its effectiveness.

Policy analysis

Gilgit-Baltistan (GB), a mountainous region in northern Pakistan, is highly vulnerable to the impacts of climate change due to its unique geographical, ecological, and socio-economic conditions (Ahmed et al., 2023). The region is characterized by its fragile ecosystem, reliance on agriculture, and limited infrastructure, making it susceptible to climate-induced disasters such as glacial melt, floods, landslides, and changing weather patterns (Asif et al., 2024). This policy analysis explores the current state of climate change in Gilgit-Baltistan, evaluates the existing climate actions and policies, identifies gaps, and provides recommendations for enhancing climate resilience.

Gilgit-Baltistan is home to some of the largest glaciers outside the polar regions (Nosheen et al., 2023). Rising temperatures accelerate

glacial melt, leading to increased glacier lake outburst floods (GLOFs), which pose significant risks to local communities (Jilani et al., 2021). The region is experiencing unpredictable and intense rainfall, which increases the frequency of flash floods and landslides, damaging infrastructure, disrupting agriculture, and threatening lives (Khan et al., 2022a). Agriculture is the main livelihood for the people of Gilgit-Baltistan, but changing weather patterns, reduced water availability, and soil erosion adversely affect crop yields and food security (Iqbal et al., 2022). Climate change is threatening the region's unique biodiversity, including alpine flora and fauna, which are highly sensitive to temperature and precipitation changes (Khurshid et al., 2023).

Figure 1 shows that Gilgit-Baltistan's approach to climate change includes a combination of national policies, regional initiatives, and community-based adaptation measures. Key policies and actions include:

1. National climate change policy (NCCP) 2012: although primarily a national policy, the NCCP outlines several adaptation and mitigation measures relevant to mountainous regions like GB, including water resource management, disaster risk reduction, and sustainable agriculture (Qazlbash et al., 2021).
2. Glacial lake outburst flood (GLOF) projects: initiatives like the GLOF-II project, supported by the United Nations Development Programme (UNDP), aim to strengthen early warning systems and build infrastructure to mitigate the impact of glacial floods in GB (Rahmat et al., 2023).
3. Community-based adaptation: local NGOs and community organizations are actively involved in implementing small-scale adaptation projects, such as water conservation, afforestation, and climate-resilient farming practices (Rajeev and Nagendran, 2023).
4. Provincial disaster management authority (PDMA): the PDMA is responsible for coordinating disaster response and implementing disaster risk reduction strategies in the region (Raza et al., 2023).
5. Promotion of sustainable tourism: efforts are being made to promote eco-friendly tourism, reduce carbon footprints, and

raise awareness about the importance of preserving the region's fragile environment (Masud and Khan, 2024).

Despite ongoing efforts, several challenges and gaps hinder effective climate action in Gilgit-Baltistan. GB lacks a tailored climate policy that addresses its unique vulnerabilities (Riaz and Dupar, 2022). The absence of a localized climate strategy limits the effectiveness of national policies in addressing region-specific issues (Akhtar, 2024). Limited financial resources, technical expertise, and institutional capacity constrain the ability of local government bodies to implement climate adaptation and mitigation measures effectively. There is a lack of comprehensive climate data and research specific to GB, which hampers the ability to develop targeted and evidence-based interventions (Riaz et al., 2024). Poor infrastructure, including limited road access and weak communication networks, exacerbates the impact of climate-induced disasters and hinders timely disaster response (Fahad et al., 2023). While community-based initiatives exist, there is a need for broader engagement and awareness-raising to ensure that local communities are fully informed and actively participate in climate adaptation efforts (Farhan et al., 2022). To address these challenges and build climate resilience in Gilgit-Baltistan, the following policy recommendations are proposed:

1. Formulate a climate adaptation strategy specifically tailored to the needs of Gilgit-Baltistan, focusing on water resource management, agriculture, disaster risk reduction, and biodiversity conservation.
2. Enhance the capacity of local government bodies, such as the PDMA and environmental agencies, through training, financial support, and partnerships with national and international organizations.
3. Invest in research and data collection to improve understanding of local climate dynamics, glacial behavior, and ecosystem responses. Establish a regional climate observatory to monitor and analyze climate impacts.
4. Scale up successful community-based adaptation initiatives and replicate them across the region. Promote the use of indigenous knowledge and practices in climate adaptation strategies.
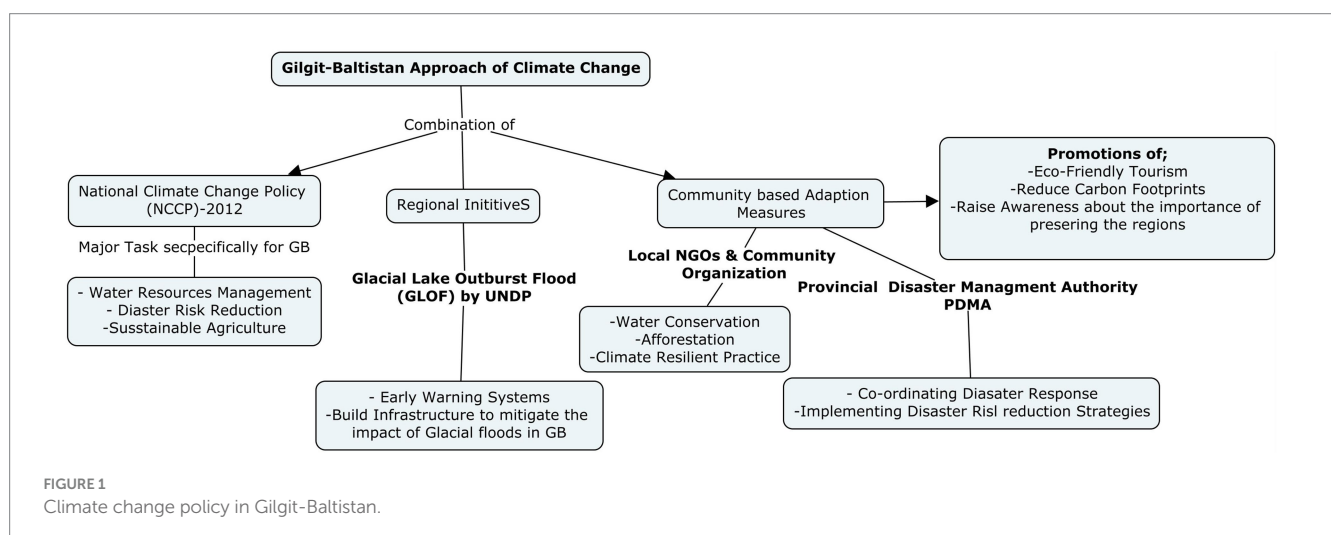

FIGURE 1
Climate change policy in Gilgit-Baltistan.

5. Strengthen early warning systems for GLOFs, floods, and other climate-related disasters. Improve communication channels to ensure timely dissemination of warnings to vulnerable communities.

6. Invest in climate-resilient infrastructure, including flood defenses, reinforced roads, and sustainable water management systems, to reduce the vulnerability of communities and assets.

7. Conduct awareness campaigns and capacity-building workshops to educate local communities about climate change risks and adaptive practices. Foster a sense of ownership and participation in climate action (Gillani et al., 2024; Masud and Khan, 2024).

Gilgit-Baltistan faces significant challenges from climate change, threatening its environment, economy, and communities (Sardar et al., 2021). While current efforts provide a foundation for climate action, there is an urgent need to strengthen and tailor policies to the region's specific needs (Satti et al., 2024). By developing a comprehensive regional strategy, enhancing institutional capacity, and fostering community engagement, Gilgit-Baltistan can build resilience against the impacts of climate change and safeguard its unique natural and cultural heritage for future generations (Shah et al., 2023). This critical analysis provides a comprehensive examination of climate challenges and actions in Gilgit-Baltistan, highlighting the urgent need for localized and strategic policy interventions to mitigate climate risks. The study addresses the critical gap in climate policy implementation and public education in Gilgit-Baltistan, a region experiencing severe climate vulnerabilities but lacking adequate representation in research and policy frameworks (Shah et al., 2024). While national climate policies offer broad guidelines, their practical execution at the local level remains inefficient due to financial, logistical, and institutional constraints (Shahid et al., 2021). Existing literature on climate change in Pakistan predominantly focuses on urban and agrarian regions like Punjab and Sindh, overlooking remote, ecologically sensitive areas such as Gilgit-Baltistan (Sohail, 2023). Moreover, studies on climate education highlight its significance in fostering climate resilience (Hoodbhoy et al., 2023; Ali, 2021), yet research on effective educational models tailored to the socio-cultural and geographical realities of Gilgit-Baltistan remains limited. Theoretical discussions on climate governance (Khan et al., 2022) emphasize the necessity of integrating scientific research into policymaking. However, a disconnect persists between high-level policy frameworks and their on-ground implementation in marginalized regions (Masud and Khan, 2024). Similarly, global studies on climate education (Memon, 2023; Bacha et al., 2021) stress the importance of localized, culturally relevant curricula but offer limited insights into how indigenous knowledge can be incorporated into formal education systems. Comparative analyses of climate adaptation strategies in mountainous regions such as the Himalayas and Andes suggest that multisectoral collaboration and community-driven approaches yield more sustainable outcomes (Hasan and Kouser, 2023; Jilani et al., 2021). Yet, Gilgit-Baltistan has not seen extensive empirical studies on such integration. To address these gaps, this study formulates the following research question:

> *"How can targeted policy analysis and climate education enhance climate action and resilience in Gilgit-Baltistan, considering the*

> *region's unique environmental, socio-economic, and institutional challenges?"*

Materials and methods

To answer this question, the study follows a four-phase mixed-method approach: (1) a bibliometric analysis of over 100 peer-reviewed articles and policy documents to identify research gaps, (2) semi-structured interviews with community leaders, religious scholars, and policymakers to assess climate awareness and educational needs, (3) documentation of climate awareness initiatives at the University of Baltistan, and (4) the development and evaluation of a context-specific educational course using a Design-Based Research framework. In mixed methods research, data integration is another name for triangulation. It describes applying various techniques, sources of information, or viewpoints to develop a more thorough grasp of a study subject. In qualitative research, triangulation is the process of using several techniques or data sources to create a detailed understanding of a phenomenon. Through the convergence of data from various sources, triangulation has also been seen as a qualitative research technique to test validity. This study consisted of the following phases;

1. The first phase of this research was a descriptive qualitative design, which was done using policy documents and bibliometric analysis. The step-by-step Research Activities of Phase 1 were to identify relevant databases (Scopus) and keywords related to climate policies, climate education, and Gilgit-Baltistan, collect bibliometric data from at least 100 peer-reviewed articles, policy documents, and reports, use bibliometric software (e.g., VOSviewer, CiteSpace) to analyze publication trends, research themes, citation networks, and influential works and identify key authors, institutions, and journals contributing to the field and compile a comprehensive report detailing findings, including publication trends, key research themes, gaps, and recommendations for future research.

2. A thorough report that highlights the current levels of climate change awareness, perceived impacts, and specific educational needs of various demographic groups, including students, teachers, NGO representatives, religious representatives, and local and political representatives within Gilgit-Baltistan, forms the basis of the second phase. The report is based on semi-structured interviews with community members.

3. The third phase contained descriptive data regarding various environmental/climate awareness campaigns collected from the University of Baltistan.

4. The fourth phase is the development of an educational course that was tailored to the local context of Gilgit-Baltistan through a Design-Based Research (DBR) strategy.

Population and sample

This study used the Scopus database. This database was selected as a research platform for many reasons. The Scopus database is a vast collection of peer-reviewed literature, including journals,

books, and conference proceedings from many countries. It is renowned for its extensive abstracts and citations. Furthermore, Scopus includes the abstracts of the majority of publications published in other databases, ensuring extensive inclusion of articles. By using the snowball sampling technique, it is possible to extend the sample to other databases derived from the current database.

Purposive sampling was used to choose two participants from each group for the second phase. The number of interview participants was set at 12, following the principle of thematic saturation, which is a widely accepted criterion in qualitative research where data collection ceases once no new themes emerge. Unlike quantitative studies that require larger samples for statistical significance, qualitative interviews prioritize depth over breadth, making a smaller, well-targeted sample sufficient for meaningful insights. Logistical constraints, such as the remote geography of Gilgit-Baltistan, limited accessibility to participants, and constraints on time and resources, also influenced the sample size. Since climate change knowledge and policy implementation involve key decision-makers and stakeholders rather than the general population, a smaller number of carefully selected respondents was appropriate for capturing diverse yet in-depth perspectives. Previous studies on climate governance and policy analysis have successfully used small sample sizes to explore localized policy gaps and educational needs, particularly in underrepresented regions. Given the exploratory and context-specific nature of this research, the chosen sample size is justified.

Participants were selected using purposive sampling to ensure representation from diverse socio-economic and demographic groups. The selection criteria focused on including key stakeholders who are directly involved in climate action efforts or significantly affected by climate policies. The sample included policymakers and government officials from the Provincial Disaster Management Authority and local environmental agencies, who provided insights into policy implementation challenges. Religious scholars were included due to their influential role in shaping community perspectives on climate-related issues. Community leaders and elders from different districts were selected to capture grassroots perspectives on climate challenges and adaptation efforts. Youth representatives, including university students and climate activists, were interviewed to assess awareness levels and engagement in climate action. Professionals from climate advocacy organizations and educational institutions also participated, offering expertise on policy and education gaps. This stratified approach ensured that the voices of both decision-makers and affected communities were incorporated, making the findings more representative of the region's climate policy landscape. The diversity of perspectives provided a holistic understanding of policy barriers, educational gaps, and the feasibility of community-driven climate initiatives in Gilgit-Baltistan.

Descriptive data collection regarding the University of Baltistan's environmental and climate awareness initiatives is essential to understand the university's contribution to the GLOF project. Quantitative data were collected through official records and event reports to determine the frequency of the workshops, campaigns, and events, as well as the number of participants. Lastly, through a design-based research strategy by two educationists a course was developed, that is highly practical and collaborative, engaging stakeholders throughout the process to ensure that the course is aligned with both academic standards and real-world needs.

Research process

Scopus is a user-friendly platform that offers support for a range of software tools to get data for bibliometric research. These tools allow users to access information such as authors, titles, publication years, cited references, abstracts, institutions, and countries (Sujaya et al., 2023). Additionally, it enables a preliminary examination of the progression of citation counts over a while and the identification of the writers and publications with the highest number of citations. The research collected data on September 12th utilizing the SCOPUS database, specifically focusing on data from the years 2014–2023. The primary search terms were "Climate Action" OR "Climate Policy" OR "Climate Change" OR "Sustainable Environment" OR "Community Driven Climate Action" OR "Global Climate." Similarly, "Education" OR "Public Education" OR "Community education" OR "Community engagement" OR "Community awareness" were used. The search query used was "[TITLE-ABS-KEY ("Climate Policy") AND TITLE-ABS-KEY ("Education")]." Retrieve articles published between 2014 and 2023, inclusive, that are in English, of type "ar" (article), and in the final publication stage. Using the specified research parameters, we discovered a total of 135 search results in the SCOPUS database. To prevent any confusion caused by similar language and to maintain focused research aimed at achieving certain goals, we deliberately refrained from seeking out any comparable phrases.

A semi-structured interview guide was developed, tailored to each demographic group, based on the key themes from Phase 1 analysis (as outlined in the guide see Annexure A). Questions focused on the participants' views on education's role in climate action, challenges faced, and specific needs for raising awareness in their communities. The semi-structured format allowed flexibility in responses while maintaining a focus on core topics like local climate initiatives, educational gaps, and the potential for collaboration between stakeholders. Interviews were conducted in person, ensuring open dialogue and follow-up questions based on participants' responses. Interviews were transcribed, and thematic analysis was used to identify recurring patterns in responses across the groups. This allowed a comparison of climate awareness levels, and perceived climate impacts, and suggested educational interventions specific to each demographic group. The findings from these interviews provide a comprehensive understanding of climate change awareness and the educational needs within different sectors of the Gilgit-Baltistan community, forming the foundation for Phase 2 of the project. This study documented workshops, campaigns, and events conducted under the GLOF project, identifying the frequency, and audience size collected during these activities that highlighted the university's role in promoting climate literacy and community engagement, which is crucial for tackling the unique environmental challenges posed by climate change in the Baltistan region. Lastly, through the Design-Based Research (DBR) strategy, is a systematic approach that focuses on designing, developing, and refining educational programs or courses through iterative cycles of analysis, design, implementation, and evaluation, a course was developed by two educationists was tailored to the local context of Gilgit-Baltistan.

Data analysis and its interpretation

This part contained the following types of data analysis;

A) Bibliometric maps
B) Thematic analysis

C) Descriptive data of workshops/campaigns/events under the GLOF project in the University of Baltistan

D) Course development

A—Bibliometric maps

This section presents a bibliometric analysis of various aspects, including the co-authorship of countries, the co-authorship of authors, and the co-occurrence of author keywords, index keywords, and terms.

Figure 2 represents a co-authorship network visualization of authors, generated using VOSviewer, depicting the collaborative patterns among researchers in a specific academic field. Each node in the network represents an author. The size of a node indicates the frequency of that author's participation in the publications within this dataset. Larger nodes reflect more frequent contributions. The lines connecting nodes signify co-authorship between authors, indicating that they have collaborated on one or more publications. The thickness of the lines indicates the strength or frequency of their collaboration; thicker lines suggest stronger or more frequent collaborative ties.

Purple Cluster (Top) includes authors like Azhar Abbas, who appears as a central figure in this group but with minimal connections, indicating limited collaboration within the dataset. Yellow Cluster (Bottom Left) consists of authors like Nawab Khan. The weak or sparse connections suggest that these authors work relatively independently or have infrequent collaborations. Yellow Cluster (Middle Right) shows connected nodes of Dilshad Ahmad and Muhammad Afzal highlighting a direct collaboration between these two authors, indicating they have likely worked together on one or more publications. Green-Purple Cluster (Bottom Center) shows Ashfaq Ahmad Shah appears connected but with limited ties, indicating solo work or collaboration with a very small network. The

color gradient from blue to green to yellow along the timeline (2020–2022) indicates the recency of collaborations. For example, the collaboration between Dilshad Ahmad and Muhammad Afzal appears in a relatively recent time frame compared to other isolated nodes. The significant distance between clusters and isolated nodes suggests a lack of interconnectivity among these groups. This implies that the authors may be focusing on different subfields or working in siloed research communities without cross-collaborations. This co-authorship visualization shows a sparse network of collaborations among authors, with distinct groups working independently. The lack of interconnectivity between clusters suggests separate research focuses or limited interdisciplinary collaboration among the researchers represented. The identified collaborative links, especially between closely connected authors, point to potential core research groups that might be driving specific subfields within the broader academic landscape. This network can help identify key collaborators and highlight areas where greater collaboration could enhance the research impact.

In Figure 3 the Yellow Cluster includes authors like Lanhai Li, Muhammad Naveed, Zulqarnain Satti, and Muhammad Shafeeque. The close connections between these authors suggest a strong collaborative group focusing on similar research themes, indicating frequent joint publications. Green Cluster consists of authors such as Atif Bilal Aslam, Ghulam Mohuddin, and others. The relatively close-knit connections suggest a smaller but strongly connected collaboration. The purple cluster, including authors like Akhter Ali, shows fewer connections compared to other groups, possibly indicating less frequent collaboration or a more specialized research focus with limited co-authorship.

Figure 4 represents a co-authorship network visualization of countries, generated using VOSviewer. It highlights the collaborative relationships between researchers from different countries, illustrating how nations are interconnected through academic research. Pakistan

FIGURE 2
Co-authorship (PK).

FIGURE 3
Co-authorship (GB).

FIGURE 4
Co-authorship (countries) at Pakistan Level.
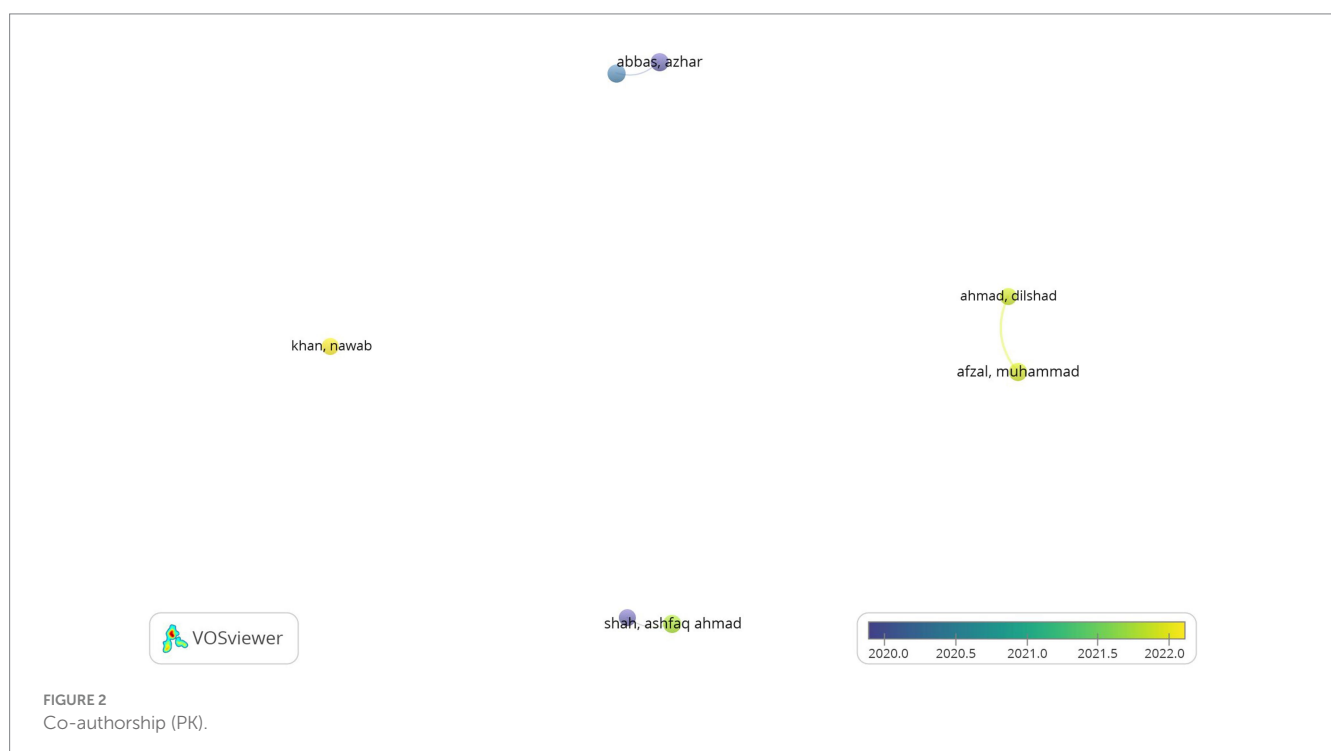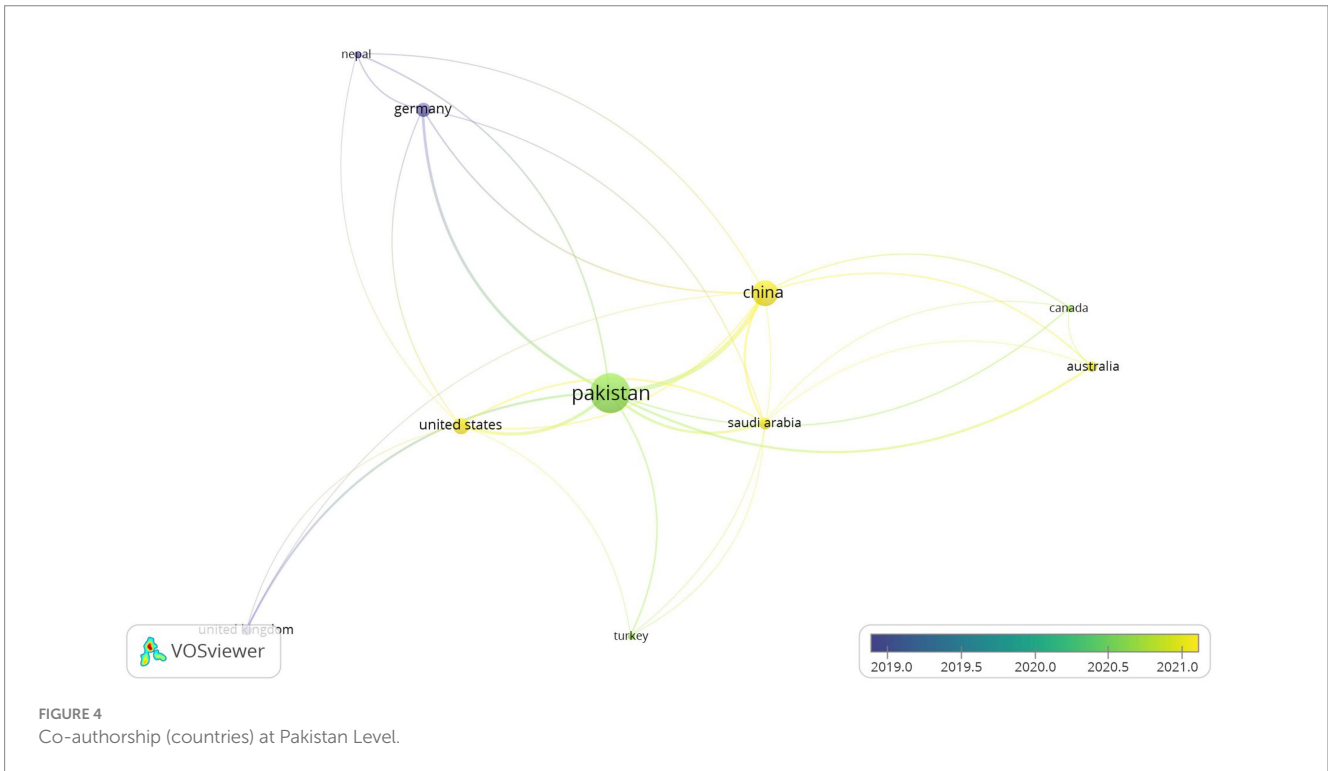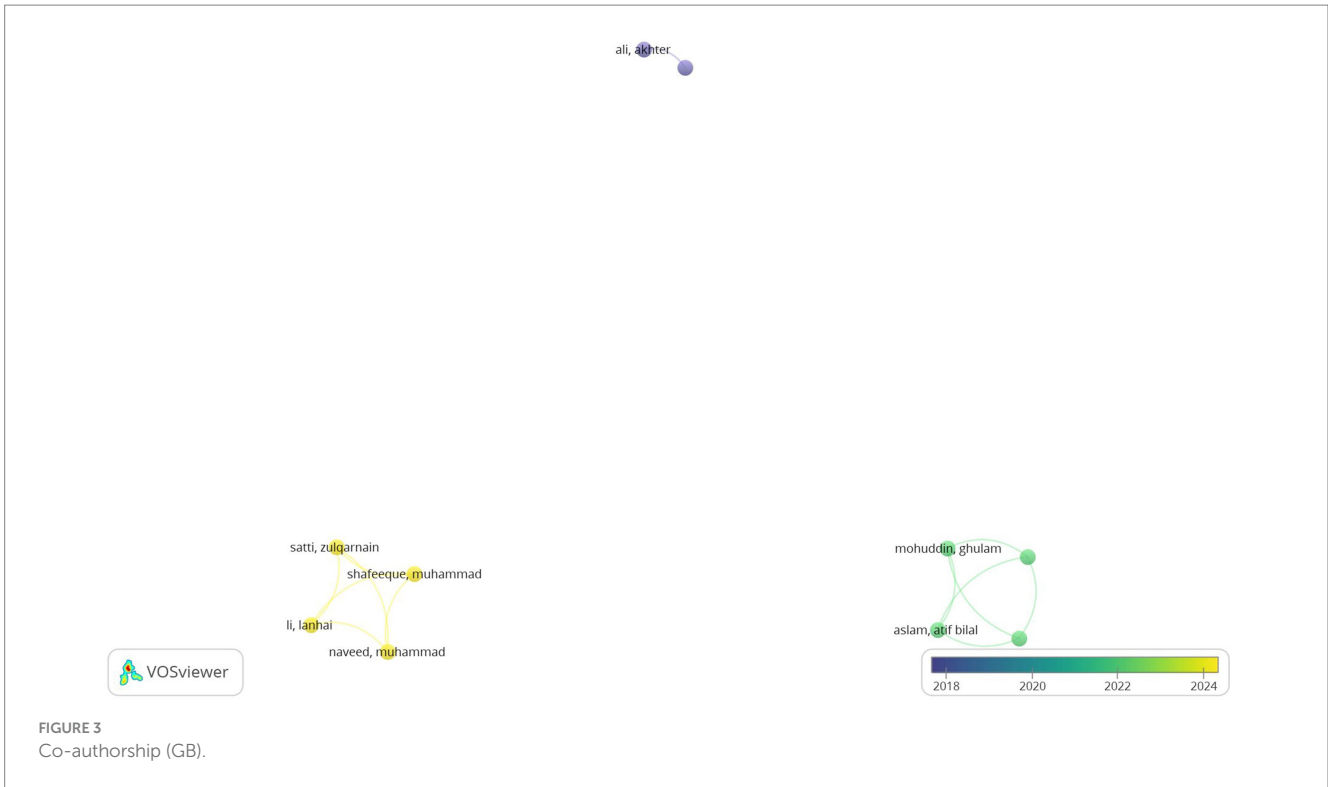
is a central node, indicating it is a key player in international research collaborations. The numerous connections to other countries demonstrate that Pakistani researchers frequently collaborate internationally. China is closely connected to Pakistan, suggesting a strong collaborative relationship between researchers from these two countries. This link is among the most prominent, indicating frequent

joint research efforts. Germany, Saudi Arabia, Australia, and Canada have significant connections with both Pakistan and China, indicating active participation in collaborative research networks. The United States and the United Kingdom, both have connections to Pakistan, suggesting notable but possibly less frequent collaborations compared to China. Nepal and Turkey are also part of the network,

showing connections primarily with Pakistan, highlighting some level of collaboration. The color gradient from blue (earlier years, around 2019) to yellow (more recent years, around 2021) illustrates the timeline of collaborations. The connections mostly shift toward yellow, indicating that the collaborative efforts have increased or remained consistent in more recent years. The proximity and interconnectedness of nodes like Pakistan and China, along with Germany, Saudi Arabia, and others, suggest these countries are actively engaging in research collaboration. Countries like the United Kingdom and Turkey, which have fewer connections, may indicate less frequent collaboration within this network or a focus on specific research topics.

This co-authorship visualization reflects an active and growing international research community centered around Pakistan, with China being a major collaborator. The presence of connections to diverse countries highlights the global nature of academic research, with significant contributions from developed and developing nations alike. The visualization emphasizes the importance of fostering international collaborations, as these partnerships can enhance the research impact, diversity of perspectives, and overall knowledge exchange across borders. The color gradient showing recent collaborative activities suggests that these connections are not only historical but also ongoing and potentially expanding.

Figure 5 is a co-occurrence network visualization of index keywords generated using VOSviewer, showing the relationships and connections between various research themes related to climate change, human impact, and environmental policies in Pakistan. Climate Change and Pakistan are the most prominent keywords, positioned centrally and highly connected to other terms, indicating that the main research focus revolves around the impacts of climate change specifically in Pakistan. Keywords like "human, ""perception, "and related terms emphasize research exploring human dimensions,

including how people perceive climate risks and their attitudes toward environmental changes. Keywords such as "agriculture, ""farmers, ""food security, "and "livelihood" highlight the focus on how climate change impacts agricultural practices and rural communities. Terms like "farmers' attitude" and "risk perception" suggest studies on how farmers understand and respond to climate risks. Terms like "vulnerability, ""risk assessment, "and "flood" suggest that the research addresses how communities, especially in vulnerable areas like Punjab and Khyber-Pakhtunkhwa, are affected by environmental hazards and the adaptation measures they adopt. Keywords such as "environmental policy, ""decision making, "and "policy analysis" indicate a strong focus on the role of governance and policy-making in addressing climate challenges, highlighting the importance of strategic planning and sustainable development. Terms like "public health, ""health education, "and "awareness" show a connection between climate change and human health, emphasizing the need for education and awareness to mitigate health impacts. The presence of terms like "human, ""nonhuman, "and "livestock" suggests a broad focus on both human and animal dimensions, reflecting interdisciplinary approaches that consider ecosystems as a whole.

Punjab, Sindh, and Khyber-Pakhtunkhwa, these regional keywords indicate that the research often focuses on specific areas within Pakistan, each with its unique climate-related challenges and adaptation needs. The color gradient from blue (earlier years, around 2019) to yellow (recent years, around 2022) shows the evolution of research topics over time. This suggests that more recent studies are increasingly focusing on adaptation strategies, policy impact, and the human perception of climate change.

This co-occurrence network visualization highlights the multidimensional nature of climate change research in Pakistan. The central focus on climate change, combined with extensive studies on human perception, agriculture, vulnerability, and policy, underscores
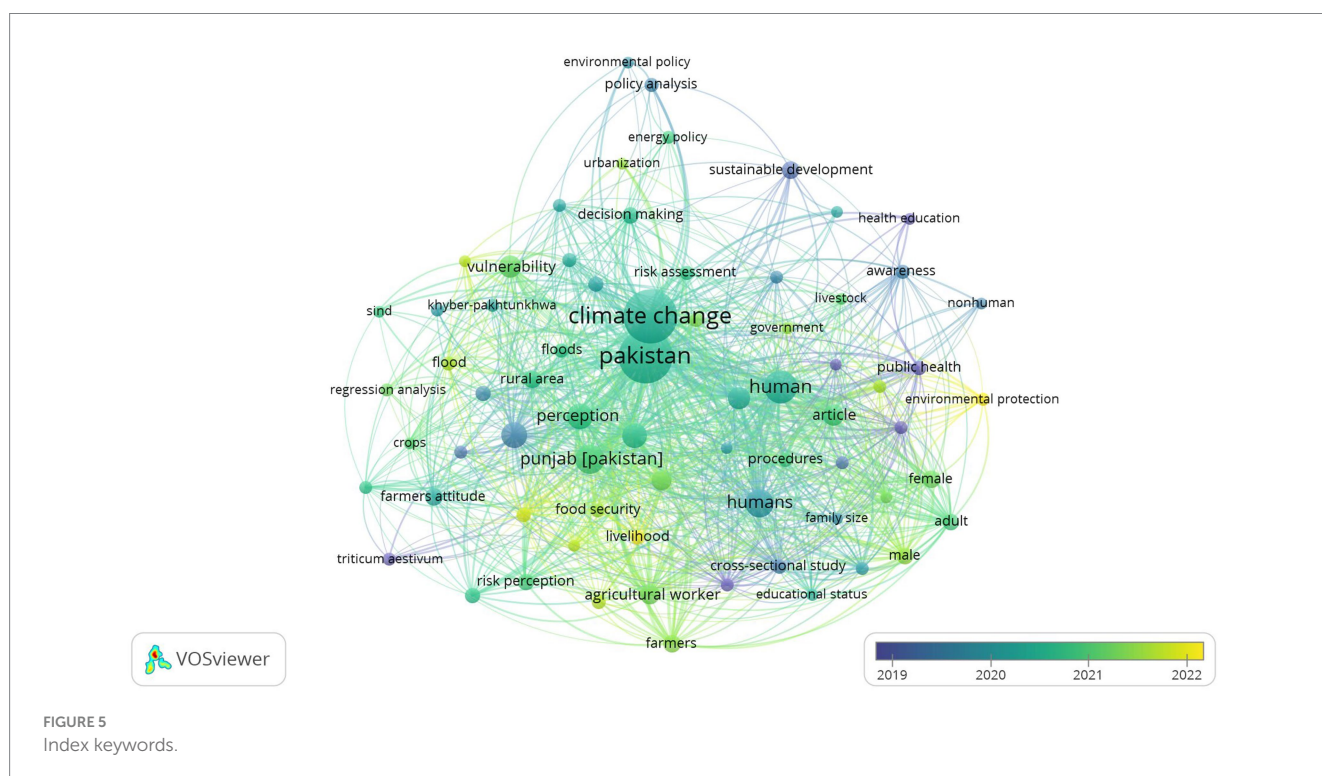

FIGURE 5
Index keywords.

a holistic approach to understanding and addressing climate impacts. The connections between governance, public health, and sustainable development reflect the broad societal implications of climate change and the critical need for integrated strategies that encompass policy, education, and community engagement. This visualization emphasizes the ongoing and evolving nature of research, with a significant emphasis on human dimensions and adaptive capacity in response to climate threats in Pakistan.

Figure 6 represents a co-occurrence network visualization of index keywords, generated using VOSviewer. This network illustrates the relationships and connections between various research topics, specifically focusing on climate change, vegetation, and environmental management in the context of Gilgit-Baltistan and related regions. Climate Change is a highly connected central node, highlighting its role as a key topic that is interconnected with various other research themes. Climate-Vegetation Interaction keyword suggests a focus on understanding how changes in climate affect vegetation, a core theme in environmental and ecological research. Normalized Difference Vegetation Index (NDVI) is a critical tool for assessing vegetation health and growth, frequently used in studies examining the impact of climate change on vegetation. Gilgit-Baltistan keyword indicates a regional focus, emphasizing studies that are geographically centered in this area, known for its unique environmental conditions. Vegetation Growth, Vegetation Response, and Vegetation Cover, these keywords are closely linked, showing a strong focus on understanding how vegetation dynamics respond to climatic factors. Climate Models and Regression Analysis, terms highlight the use of analytical and predictive tools in studying the interactions between climate and vegetation. Environmental Management and Resource Management, keywords suggest an applied focus on managing the impacts of climate change on natural resources and ecosystems. Keywords like Summer, Winter, and Seasonal Variation indicate an emphasis on studying how different seasons and climatic variations affect vegetation patterns and ecosystem health. The dense web of connections suggests a highly integrated research field where multiple keywords and themes are frequently studied together, reflecting the complexity and interrelated nature of climate and environmental research.

This co-occurrence network visualization highlights the interconnected research themes related to climate change, vegetation dynamics, and environmental management, with a particular focus on Gilgit-Baltistan. The strong interlinkages between keywords suggest a multidisciplinary approach, integrating climate science, ecology, and resource management to address the impacts of climate change. The emphasis on tools like NDVI and climate models indicates a robust use of technology and analytical methods in understanding and predicting vegetation responses to environmental changes. The network underscores the importance of studying these complex interactions to inform effective environmental and resource management strategies in the face of changing climatic conditions.

The Figure 7 a co-occurrence network visualization of author keywords generated using VOSviewer shows how frequently specific keywords are used together in academic research. The network provides insights into the main themes and research focus areas within the context of climate change, particularly in Pakistan. Climate Change is the most central and frequently connected keyword, indicating its primary role in the research focus. It serves as a nexus connecting various aspects related to environmental and societal impacts. The prominence of this keyword suggests a specific geographical focus on climate change research in Pakistan, highlighting local challenges and responses. Adaptation and Adaptation Strategies are closely linked to climate change and are crucial in studying how societies and ecosystems adjust to changing climatic conditions. Agriculture is connected to both adaptation and climate change, highlighting the importance of agriculture as a sector

FIGURE 6
Co-occurrence (index keyword-GB).
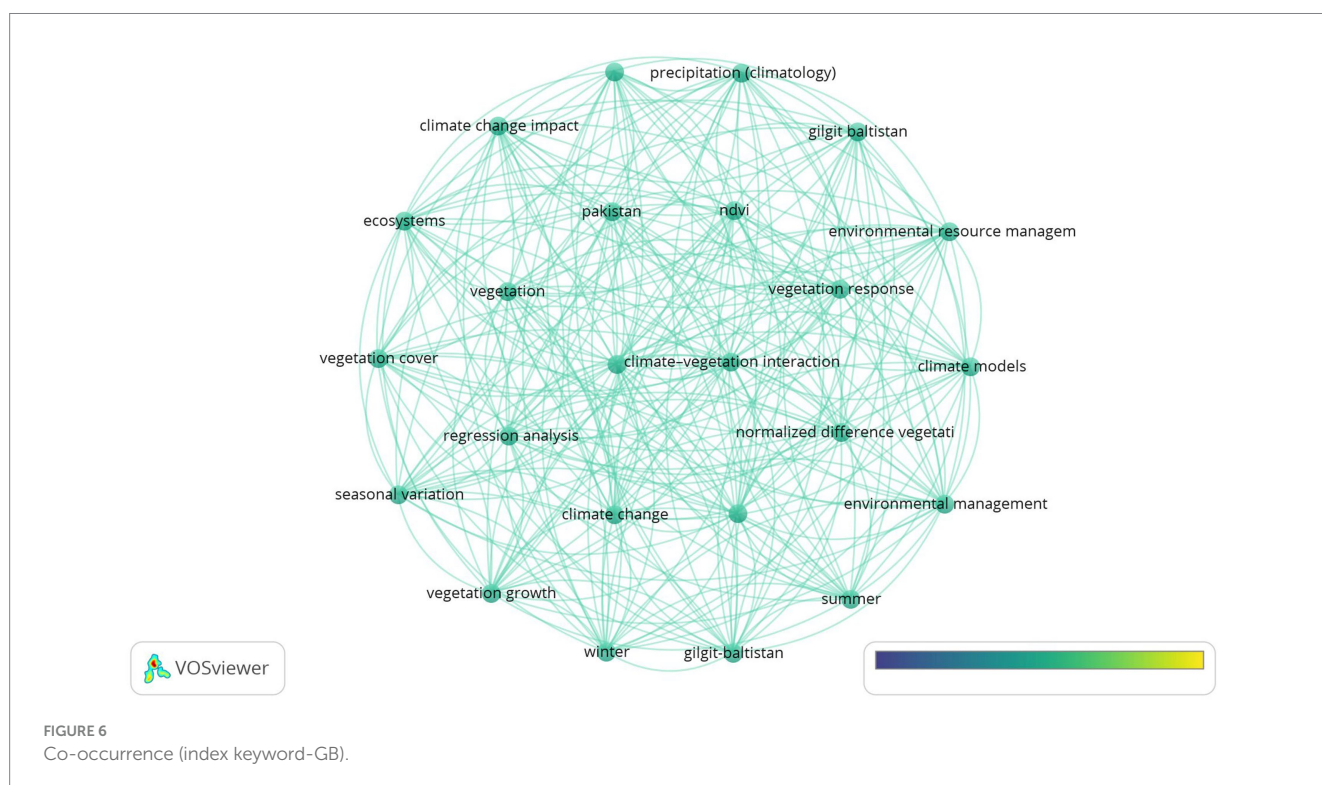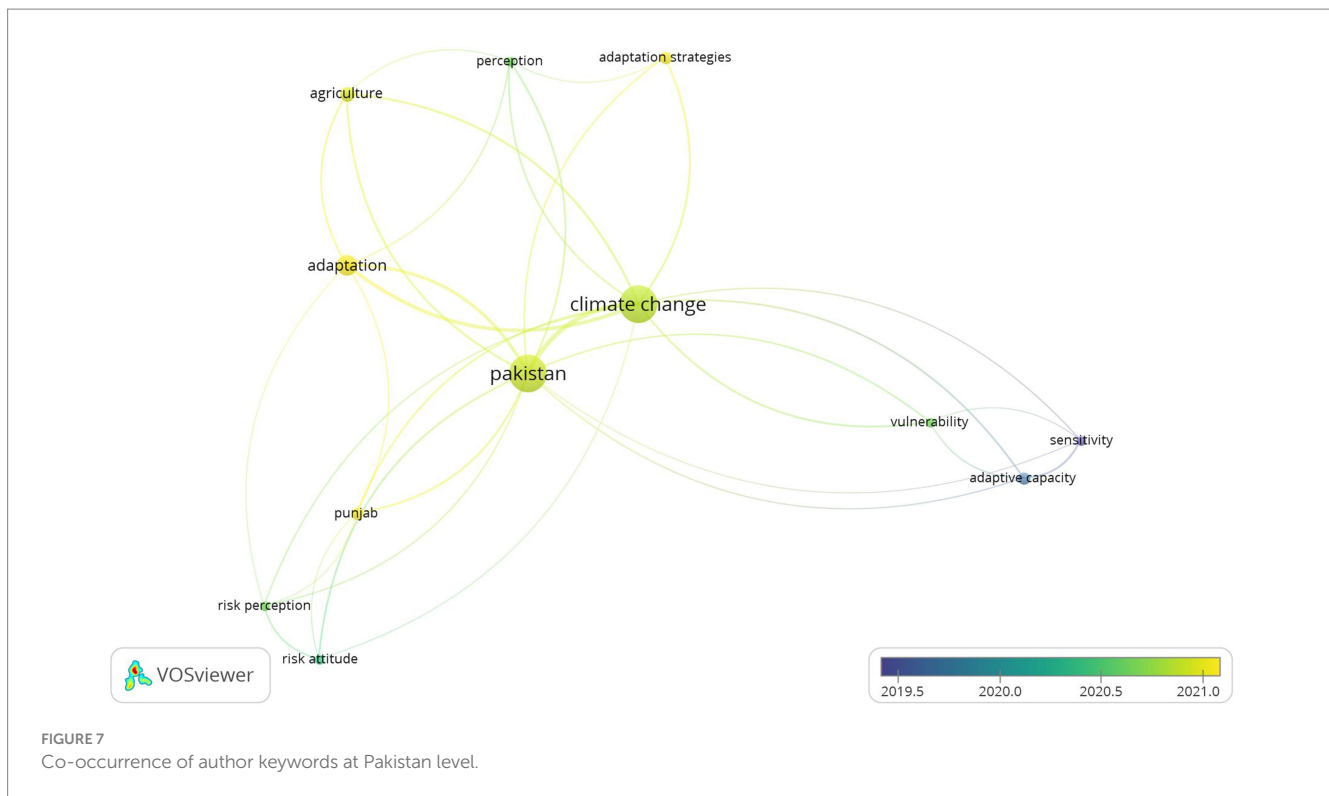
significantly affected by climatic changes and a focal point for adaptive measures. Risk Perception and Risk Attitude, these terms indicate research attention on how individuals and communities perceive and react to the risks associated with climate change, particularly in the context of adaptation strategies. Vulnerability, Sensitivity, and Adaptive Capacity are related to assessing how susceptible communities and systems are to climate impacts and their capacity to adapt. This cluster suggests a focus on resilience and vulnerability assessments, which are crucial for planning effective adaptation strategies. The inclusion of Punjab indicates specific research focusing on this region within Pakistan, which may be due to its significant agricultural base and vulnerability to climate impacts. The color gradient from blue (older, around 2019) to yellow (more recent, around 2021) illustrates the evolution of research focus over time. Keywords like "adaptive capacity" and "sensitivity" appear earlier, suggesting that these topics have been foundational in the literature, while terms like "perception" and "adaptation strategies" are more recent, highlighting emerging areas of interest. This co-occurrence network reveals that the main focus of research is on understanding climate change impacts in Pakistan, with particular emphasis on adaptation strategies. The interconnectedness of climate change with keywords related to adaptation, agriculture, and risk perception highlights a comprehensive approach to studying how climatic shifts affect different sectors and how communities respond. The geographical focus on Pakistan, particularly Punjab, underscores the importance of region-specific studies in addressing local vulnerabilities. This visualization emphasizes the multidimensional nature of climate change research, integrating social, environmental, and economic perspectives to develop more effective adaptation strategies.

Figure 8 represents a co-occurrence network visualization of author keywords, generated using VOSviewer. This type of visualization shows how frequently certain keywords appear together in academic publications, providing insight into the main themes and focus areas of the research. Climate Change is one of the most central and connected keywords, highlighting its pivotal role in the research context. It is directly linked to other key themes, showing its broad impact on various aspects of environmental and vegetation studies. Climate-vegetation interaction **is** closely tied to climate change, this keyword reflects the study of how climate factors influence vegetation, indicating a focus on understanding ecological dynamics. NDVI (Normalized Difference Vegetation Index) is a significant analytical tool used to measure vegetation health and growth, indicating its frequent use in studies related to climate and vegetation interactions. Seasonal Variations and Vegetation Growth suggest a focus on how seasonal changes affect vegetation patterns, possibly examining the impact of different seasons on plant growth and ecosystem dynamics. Gilgit Baltistan, the inclusion of this specific geographical location highlights a regional focus within the research, likely indicating that many studies are centered on this area, particularly in the context of climate and vegetation dynamics. The interconnected nature of all these keywords suggests a highly integrated research field where the interactions between climate, vegetation, and specific regional conditions (like in Gilgit Baltistan) are of primary interest. The network emphasizes how studies often link climate change with vegetation responses, using tools like NDVI to measure these impacts quantitatively.

This co-occurrence network visualization highlights the main themes within the research field, focusing on the complex interactions between climate change and vegetation dynamics. The frequent use of keywords like NDVI indicates a strong reliance on quantitative measures to assess vegetation health and growth. The specific focus on Gilgit Baltistan suggests that the studies are particularly relevant to this region, likely exploring how its unique environmental conditions

FIGURE 8
Co-occurrence of author keywords at Gilgit-Baltistan.
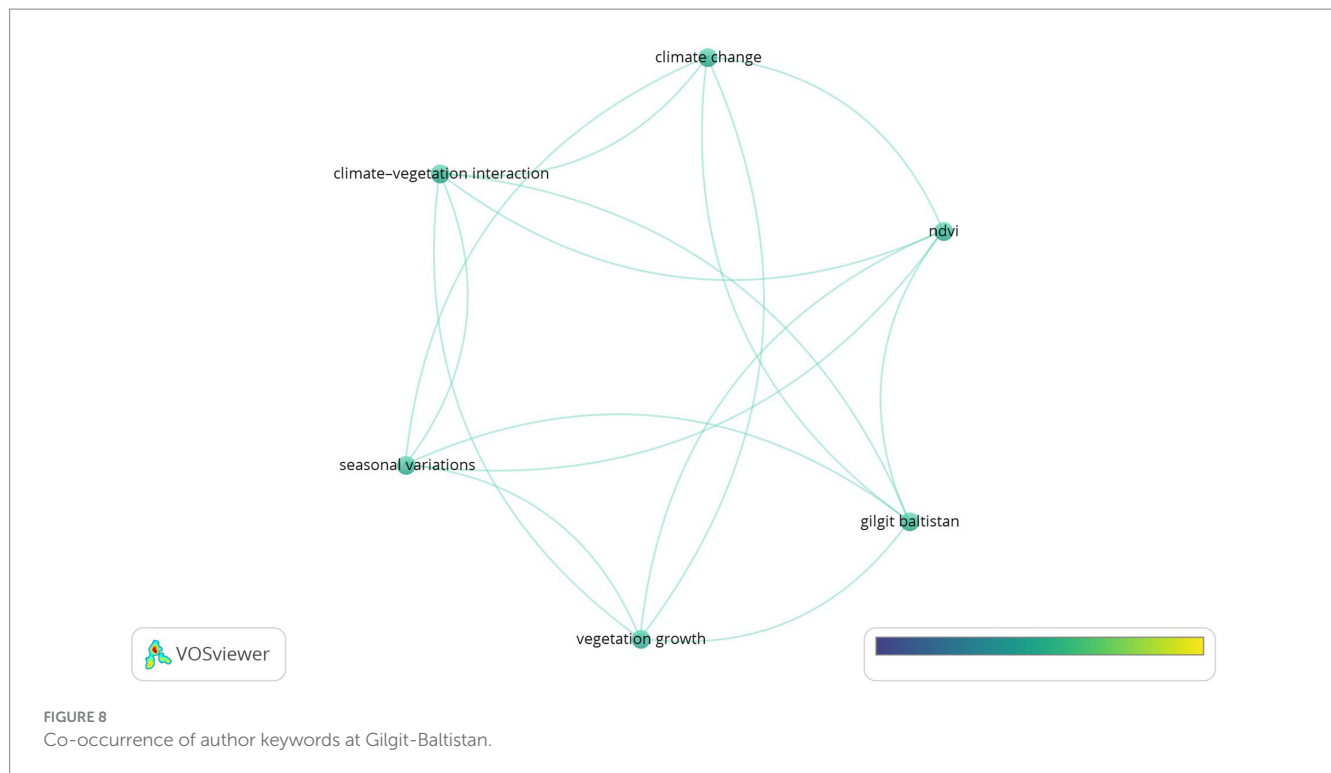
respond to broader climate changes. This network underscores the importance of understanding climate-vegetation interactions, especially in sensitive regions where climate impacts can be profound.
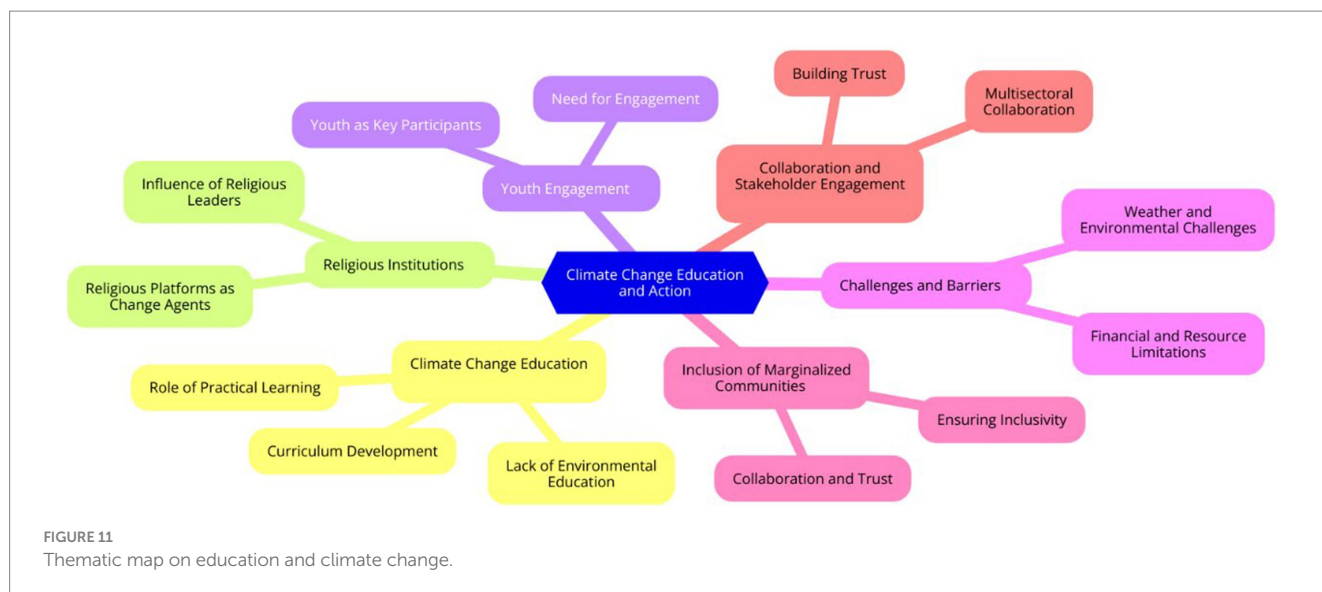
Figure 9 shows a co-occurrence network visualization of terms generated using VOSviewer, showing the relationships and connections between various research themes related to climate change, human impact, and environmental policies in Pakistan. Climate Change and Pakistan are the most prominent keywords, positioned centrally and highly connected to other terms, indicating that the main research focus revolves around the impacts of climate change specifically in Pakistan. Keywords like "human, ""perception," and related terms emphasize research exploring human dimensions, including how people perceive climate risks and their attitudes toward environmental changes. Keywords such as "agriculture," "farmers," "food security," and "livelihood" highlight the focus on how climate change impacts agricultural practices and rural communities. Terms like "farmers' attitude" and "risk perception" suggest studies on how farmers understand and respond to climate risks. Terms like "vulnerability," "risk assessment," and "flood" suggest that the research addresses how communities, especially in vulnerable areas like Punjab and Khyber-Pakhtunkhwa, are affected by environmental hazards and the adaptation measures they adopt. Keywords such as "environmental policy," "decision making," and "policy analysis" indicate a strong focus on the role of governance and policy-making in addressing climate challenges, highlighting the importance of strategic planning and sustainable development. Terms like "public health," "health education," and "awareness" show a connection between climate change and human health, emphasizing the need for education and awareness to mitigate health impacts. The presence of terms like "human," "nonhuman," and "livestock" suggests a broad focus on both human and animal dimensions, reflecting interdisciplinary approaches that consider ecosystems as a whole. Punjab, Sindh, and Khyber-Pakhtunkhwa, these regional keywords indicate that the research often focuses on specific areas within Pakistan, each with its unique climate-related challenges and adaptation needs. The color gradient from blue (earlier years, around 2019) to yellow (recent years, around 2022) shows the evolution of research topics over time. This suggests that more recent studies are increasingly focusing on adaptation strategies, policy impact, and the human perception of climate change (Figure 9).

This co-occurrence network visualization highlights the multidimensional nature of climate change research in Pakistan (Figure 10). The central focus on climate change, combined with extensive studies on human perception, agriculture, vulnerability, and policy, underscores a holistic approach to understanding and addressing climate impacts. The connections between governance, public health, and sustainable development reflect the broad societal implications of climate change and the critical need for integrated strategies that encompass policy, education, and community engagement. This visualization emphasizes the ongoing and evolving nature of research, with a significant emphasis on human dimensions and adaptive capacity in response to climate threats in Pakistan.

B—Thematic analysis

Inductive coding involves identifying themes, patterns, or categories directly from the data without imposing predefined categories (Tunio et al., 2024). The thematic map on Climate Change Education and Action illustrates key themes around climate change education, religious involvement, youth engagement, and challenges related to implementing climate action. Thematic analysis was used to extract key themes from the qualitative data collected through semi-structured interviews and policy documents. The process followed an

FIGURE 9
Co-occurrence of terms.

FIGURE 10
Holistic terms for research on climate change in pakistan.

inductive coding approach, allowing patterns and categories to emerge naturally from the data rather than being predefined (Ud Din et al., 2023). Thematic extraction was conducted in three stages. The first stage involved open coding, where all interview transcripts were carefully reviewed, and relevant excerpts were assigned preliminary codes based on frequently occurring ideas, phrases, and patterns. To ensure a comprehensive interpretation and reduce bias, two researchers independently generated these codes. The second stage

involved axial coding, in which the initial codes were grouped into broader categories based on conceptual similarities. Relationships between these categories were examined to develop overarching themes such as barriers to policy implementation, climate awareness gaps, the role of religious institutions, and youth engagement challenges. Any discrepancies in coding were discussed and refined to enhance clarity and consistency. The third stage involved validation through triangulation, where findings from the interviews were

FIGURE 11
Thematic map on education and climate change.

cross-checked with results from policy analysis, literature reviews, and environmental awareness data from the University of Baltistan. Additionally, member checking was conducted by having selected participants review the extracted themes to confirm whether the interpretations accurately reflected their perspectives. This multi-step validation process ensured that the themes were representative of the data and aligned with broader policy and educational trends in climate action.

The thematic map on Climate Change Education and Action illustrates the interplay between climate education, religious institutions, youth engagement, and the challenges related to implementing climate action (Figure 11). One key theme is the lack of environmental education, particularly among religious scholars, despite their academic backgrounds. This highlights the need for curriculum development to integrate climate change education into Islamic teaching at all levels, focusing on practical learning through hands-on activities and workshops. Religious institutions are identified as essential platforms for raising awareness, with religious leaders playing a pivotal role as trusted community figures in promoting environmental consciousness. Youth engagement is also emphasized, as young people are seen as crucial participants in climate action efforts, though they face challenges like unemployment and limited resources. The map stresses the importance of engaging youth through educational programs and workshops to foster active involvement in climate action. However, challenges and barriers such as financial limitations and adverse weather conditions complicate efforts, especially for marginalized groups and religious institutions. The inclusion of marginalized communities is vital, emphasizing the need for trust-building and collaboration across religious, social, and environmental sectors. Lastly, multisectoral collaboration between religious scholars, educational institutions, communities, and external organizations, such as NGOs, is critical for effective climate change initiatives. Trust among stakeholders is deemed essential for successful climate action and community engagement.

Figure 12 illustrates the pivotal role of education in addressing climate change, emphasizing the development of a comprehensive climate change curriculum through both formal and informal education channels. It highlights the need for interdisciplinary collaboration, particularly between social and natural sciences, to ensure a holistic approach to climate education. Additionally, the diagram stresses the importance of integrating climate change topics into technical and higher education curricula. Local initiatives, particularly community awareness programs, are shown as critical for fostering engagement at the grassroots level. These initiatives, such as eco-tourism and sustainable practices, contribute to economic opportunities for local communities while promoting conservation efforts. The diagram also acknowledges the challenges related to funding and the necessity for research collaborations to support educational and environmental programs, particularly in areas like solid waste management. Overall, it presents a multi-faceted approach that involves collaboration, education, and practical solutions to combat climate change.

C—Descriptive data of workshops/campaigns/events

Table 1 contains a list of workshops, campaigns, and events organized under the GOLF Project at the University of Baltistan, focusing on environmental science and awareness. This table lists a variety of activities, including celebrations of important environmental days (e.g., World Environment Day), awareness walks, and cleanup campaigns. These events primarily target undergraduate students, faculty, and representatives from environmental organizations like the UNDP and WWF. The main focus of these events is environmental education and awareness, particularly related to climate change, disaster risk reduction, water conservation, and waste management.

Some activities also include practical initiatives, like tree planting and clean-up drives. Many of these events are conducted in collaboration with external organizations such as the UNDP, WWF, and local government bodies like the District Administration of Shigar, Rescue 1,122, and the Gilgit-Baltistan Waste Management Company (GBWMC). The target audience for these workshops and campaigns includes university students and faculty, as well as school students and representatives from environmental and development organizations. The table is a comprehensive overview of environmental

FIGURE 12
Education's role in climate change.
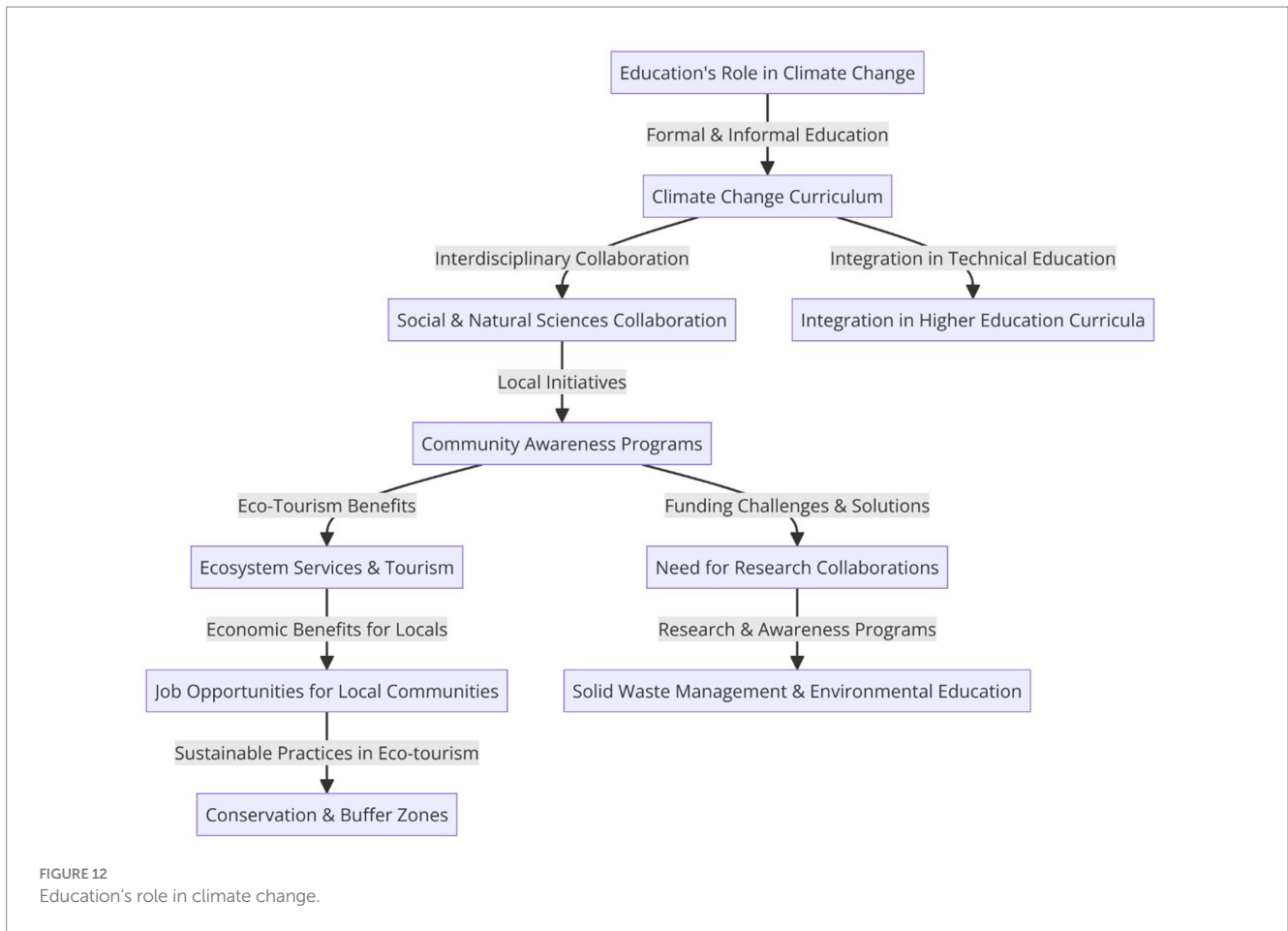
outreach and engagement activities designed to promote sustainability and environmental stewardship within the region.

D—Course development

The development of the one-credit hour course, "Climate Change Education and Action in Gilgit-Baltistan: Theory and Practice," was guided by a Design-Based Research (DBR) approach, ensuring that it was tailored to the specific regional context and needs of Gilgit-Baltistan. The process began with an in-depth analysis of climate change literature and the unique environmental challenges facing the region, such as glacial lake outburst floods (GLOFs) and water scarcity. Key insights were drawn from studies and local case examples, emphasizing the importance of climate education, community engagement, and multisectoral collaboration. Local stakeholders, including educational institutions, NGOs, and religious leaders, were involved in identifying gaps in environmental awareness and the need for practical, community-driven solutions. The course was designed to balance theoretical knowledge in a classroom setting with hands-on field activities, ensuring that students gain both academic understanding and practical skills for addressing climate challenges. Throughout its development, the course incorporated feedback from local educators, climate experts, and community representatives, ensuring that it aligns with the academic standards of the University

of Baltistan while meeting the practical needs of the region. The inclusion of field activities, such as tree planting and disaster preparedness exercises, was essential to make the learning experience highly relevant and context-specific for the students.

This course provides students with both theoretical knowledge and practical skills essential for climate action, emphasizing the unique environmental challenges of Gilgit-Baltistan (Table 2).

Discussion

The document provides a comprehensive bibliometric analysis of publication trends, key research themes, and influential works related to climate change, environmental management, and policy impacts in regions like Gilgit-Baltistan (GB) and broader Pakistan. Below is a critical identification of gaps and foundational suggestions for future research and policy development based on the findings identified limited interdisciplinary collaboration in research and policy. The analysis of co-authorship networks shows a fragmented research landscape with distinct clusters of authors working independently or within limited groups. There is a noticeable lack of interdisciplinary collaboration, especially among researchers focusing on different subfields such as climate science, social sciences, and policy analysis (Ullah et al., 2024). The co-occurrence analysis of keywords highlights that the majority of research is concentrated in specific regions,

TABLE 1 List of workshops/campaigns/events.

No	Names of Workshops/Campaigns /Events Under the GOLF Project	Participants/Audience nature (School/College/University students and Faculty/NGO)
1	World Environment Day 2022	Undergraduate University Students and Faculty
2	Awareness Walk on the Final Day of Sports Gala 2023	Students and faculty from various departments
3	World Environment Day 2023	Undergraduate University Students and Faculty
4	Volunteer of Green Society Went to Concordia	Student & Faculty of the Environmental Department
5	World Water Day	The staff of WWF-Pakistan and students and faculty of the Department of Environmental Science, UOBS
6	World Environment Day 2024 (During Sports Week)	Undergraduate Students and Faculty of UOB
7	International Disaster Risk Reduction Day Celebrated at Commissioner's Office (October 13, 2023)	Students and Faculty of Environmental Students and representatives of UNDP and GBDMA
8	Plantation Day 2023	Undergraduate University Students and Faculty
9	Sarfaranga/Event Cleaup Compaign	Undergraduate University Students and Faculty
10	Plantation At GB Scouts Headquarters	Undergraduate University Students and Faculty
11	ACT TODAY: SAVE TOMORROW (A Talk and Penal Discussion on Climate Change)	Undergraduate University Students
12	Revive Nature, Stop Flood Risks" (A Debate on Climate Change)	Inter Boys College Astore
13	Environmental Awareness Camp during Sarfaranga Jeep Rally	Students and faculty of the Department of Environmental Science and UNDP representatives
14	Participated in a Climate Change Awareness Session among different schools in collaboration with P&DD.	Faculty of the Department of Environmental Sciences and Students of schools
15	Sarfaranga Desert and Indus River Bank Clean-up Drive in collaboration with District Administration Shigar, UNDP, GBWMC, and WWF.	Representatives of the Department of Environmental Science at the University of Baltistan Skardu (UoBS), District Administration Shigar, United Nations Development Programme (UNDP), World Wildlife Fund (WWF), and Gilgit-Baltistan Waste Management Company (GBWMC).
16	Department of Environmental Science, University of Baltistan Skardu Raises Awareness in Collaboration with Rescue 1,122	Environmental Science Department Students and Faculty
17	Awareness and Training Session on Climate Change and Disaster Risk Management	Environmental Science Department Students
18	Field Trip to Shigar District, Skardu	Environmental Science Department Students
19	A one-day workshop on the implementation of the Basel Convention's amendments for enhanced control of plastic waste movements.	Environmental Science Department Students
20	Feasibility visit for the installation of a Kitchen Wastewater Treatment Plant through the WRAP Project at UOBS	WWF Team and Environmental Science Department faculty

particularly Punjab, Sindh, and Khyber-Pakhtunkhwa, with relatively less focus on Gilgit-Baltistan despite its significant climate vulnerability. This regional bias limits the generalizability of findings across Pakistan (Ullah et al., 2023). Keywords such as "policy analysis," "environmental policy," and "decision making" are central to the analysis, suggesting a strong focus on governance. However, there is a gap in translating these policies into actionable local strategies, particularly in remote areas like GB, where policy implementation is weak due to logistical and administrative challenges (Usman et al., 2023a, 2023b). The analysis reveals that while themes like "vulnerability," "resilience," and "adaptation" are frequently studied, there is insufficient emphasis on community-based adaptation strategies that incorporate local knowledge and practices. This gap is critical in areas like GB, where indigenous knowledge could play a significant role in enhancing climate resilience (Afzal et al., 2023). A significant gap identified is the lack of robust data collection and monitoring systems specific to regions like GB (Usman et al., 2021).

The reliance on tools like NDVI (Normalized Difference Vegetation Index) highlights the importance of technology in studying vegetation and environmental changes, yet data is often outdated or inconsistent. The document shows emerging research themes related to education, awareness, and public health impacts of climate change. However, there is a lack of structured educational programs targeting vulnerable communities in GB, which are crucial for empowering local populations to adapt and mitigate climate risks (Ehsan et al., 2021). This analysis provides a strategic direction for researchers and policymakers aiming to enhance climate resilience in Gilgit-Baltistan and similar vulnerable regions. By addressing these gaps, future research can contribute to more effective and equitable climate policies that support sustainable development and community empowerment.

The policy analysis revealed stark contrasts between the effectiveness of national and regional climate policies in Gilgit-Baltistan (Villanthenkodath and Velan, 2022). The National Climate Change Policy (NCCP) of 2012 provides a broad

TABLE 2 Course development.

Course title: climate change education/civic education

Course code: XXX

Credit hours:1 credit hour (2 parts: theory and field activities)

Course description:

This course is designed for undergraduate students across all disciplines to introduce the basic concepts of climate change and its specific impacts on the Gilgit-Baltistan region. The course is divided into two parts:

1. Theoretical Part (Classroom setting): Provides foundational knowledge about climate change, its regional implications, and the role of education and community engagement in addressing climate challenges.

2. Practical Part (Field activities): Engages students in hands-on activities within their community to explore real-life climate challenges, adaptation strategies, and the importance of local environmental stewardship.

Learning outcomes:

By the end of the course, students will:

- Recognize the importance of education and community involvement in addressing climate change.
- Participate in community-based climate adaptation activities, focusing on practical solutions for environmental issues in the region.
- Gain experience in fieldwork, enhancing their skills in environmental monitoring, disaster preparedness, and sustainability efforts.

Course structure and breakdown

Total hours:

- Classroom (Theory): 9 h
- Fieldwork (Practical): 6 h
- Total contact hours: 15 h

Part 1: theoretical component (Classroom)

Duration: 9 h (1.5 h per week for 6 weeks)

Key topics:

1. Introduction to climate change (1.5 h):
- The science of climate change: causes, impacts, and key global patterns.
- Overview of climate change in Gilgit-Baltistan: glacial melt, GLOFs, water scarcity.
2. Environmental challenges in Gilgit-Baltistan (1.5 h):
- Climate-induced risks: floods, droughts, and their impact on local communities.
- Agricultural impacts and food security in the region.
3. Community engagement in climate action (1.5 h):
- The role of religious, educational, and social institutions in raising climate awareness.
- Integrating climate education into local schools, universities, and religious teachings.
4. Practical adaptation strategies (1.5 h):
- Local adaptation efforts: water conservation, sustainable agriculture, and disaster preparedness.
- Case studies of successful community-based adaptation projects in Gilgit-Baltistan.
5. Multisectoral collaboration and trust building (1.5 h):
- The importance of collaboration between government, NGOs, and local communities.
- Engaging youth and marginalized communities in climate initiatives.
6. Preparation for fieldwork (1.5 h):
- Overview of fieldwork activities: environmental monitoring, tree planting, and disaster preparedness exercises.
- Group planning and discussion for upcoming field activities

Part 2: field activities (Practical)

Duration: 6 h (Fieldwork conducted over two full days)

Field activity themes:

1. Day 1: tree planting and environmental monitoring (3 h):
- Students will participate in a local tree-planting initiative in collaboration with environmental organizations (WWF, UNDP, etc.).
- Monitoring vegetation health using basic tools (e.g., NDVI for tracking plant growth), and identifying impacts of climate change on local flora.
- Discussion on the importance of afforestation in preventing land degradation and promoting local biodiversity.
2. Day 2: community disaster preparedness and water conservation (3 h):
- Students will work with local authorities and NGOs (Rescue 1122, District Administration) on disaster preparedness exercises.
- Practical training on early warning systems for glacial lake outburst floods (GLOFs) and other climate-induced hazards.
- Water conservation activities: assessment of water usage in a local village, and brainstorming potential water-saving techniques.

(Continued)

TABLE 2 (Continued)

Assessment and evaluation:
1. Classroom participation (30%):
• Active participation in lectures and discussions.
• Short quizzes after each theoretical topic.
2. Fieldwork participation (40%):
• Engagement in tree-planting, environmental monitoring, and community-based activities.
• Reflective report (500 words) on fieldwork experience, discussing how the practical activities related to climate action in Gilgit-Baltistan.
3. Final presentation (30%):
• Group presentations summarizing both theoretical and practical components.
• Focus on how students can contribute to ongoing climate action initiatives in their local communities.
Required resources:
• Readings on climate change science and regional case studies (provided by instructor).
• Collaboration with local organizations such as WWF, UNDP, and Rescue 1122 for fieldwork.
References and suggested readings:
1. National climate change policy 2012 (Pakistan).
2. Gilgit-Baltistan Glacial lake outburst flood (GLOF) project reports.
3. "Sustainable development and climate action in mountainous regions" – UNDP reports.

framework for climate adaptation and mitigation but lacks specificity in addressing the unique vulnerabilities of mountainous regions like Gilgit-Baltistan (Afzal et al., 2023). One government respondent noted, "The national policy talks about flood management, but it does not mention glacial lake outburst floods, which are our biggest concern." Regional policies, such as those implemented by the Provincial Disaster Management Authority (PDMA), offer more localized solutions but suffer from weak enforcement and insufficient funding. A PDMA official admitted, "We have climate adaptation strategies in place, but without sustained financial support and technical expertise, they remain largely ineffective." Additionally, community-based adaptation initiatives, often led by non-governmental organizations, have proven more effective in engaging local populations but lack formal integration into the policy framework. A respondent from an NGO explained, "We work on small-scale water conservation and afforestation projects, but there is no coordination between our efforts and the government's climate policies." This comparison highlights the need for a more integrated approach that bridges national policies with local implementation strategies, ensuring that climate adaptation measures are both context-specific and effectively enforced (Yao and Khan, 2022).

The findings from the thematic analysis on climate change education and action reveal a complex interplay between education, religious institutions, youth engagement, and multisectoral collaboration. One of the most significant insights is the gap in environmental education among religious scholars, despite their academic backgrounds. This lack of knowledge highlights the need for curriculum development, particularly in regions like Gilgit-Baltistan, where religious leaders hold significant influence (Bacha et al., 2021). The integration of climate change education into Islamic teachings presents a promising solution. Religious scholars, as trusted community figures, could play a pivotal role in promoting environmental stewardship, especially if climate education is framed within the moral and ethical guidelines of religious teachings. However, implementing such curriculum changes poses challenges, including potential resistance from religious institutions and the need

for external support and resources to make these educational programs viable (Fahad et al., 2023).

Religious institutions are identified as key platforms for climate action, especially in communities where faith-based leadership is deeply respected. Religious leaders have the potential to raise environmental consciousness, but the effectiveness of this approach depends on their understanding of climate issues (Farhan et al., 2022). Capacity-building within religious institutions is essential to ensure that leaders are knowledgeable and able to advocate effectively for environmental protection. While religious institutions can link environmental action with spiritual and ethical teachings, they may also face challenges in balancing these new responsibilities with their traditional roles.

Youth engagement emerges as another critical theme. Young people are seen as crucial participants in climate action, yet they face systemic challenges such as unemployment and a lack of resources (Akhtar, 2024). These barriers not only hinder their participation but also reflect broader issues of socio-economic exclusion, particularly for marginalized groups. The focus on youth education through workshops and practical initiatives is an important step toward empowerment, but long-term strategies are needed to ensure that young people can transition from learning to active participation in climate action. Addressing unemployment and providing opportunities for hands-on involvement in environmental projects would enhance the role of youth as agents of change.

The analysis also underscores the numerous challenges related to implementing climate action, particularly for marginalized communities and religious institutions. Financial constraints and adverse weather conditions are significant obstacles in regions like Gilgit-Baltistan, where economic hardships and geographic factors exacerbate difficulties in organizing and sustaining climate initiatives. The importance of trust-building and collaboration between various sectors—religious, social, and environmental—is emphasized, as these efforts require the combined strengths of multiple stakeholders to succeed (Gillani et al., 2024). However, collaboration alone is insufficient without targeted support and resource allocation, especially for marginalized communities that often have the least capacity to respond to climate change impacts.

Multisectoral collaboration is identified as a vital component of effective climate change education and action (Ali et al., 2022). The findings emphasize the importance of cooperation between religious scholars, educational institutions, communities, and external organizations like NGOs. This approach fosters trust among stakeholders, which is crucial for the success of climate initiatives. However, the effectiveness of these collaborations' hinges on sustainable partnerships with clear roles, long-term commitments, and the necessary funding to support ongoing projects (Ali, 2021). In particular, interdisciplinary collaboration between social and natural sciences, as highlighted in the analysis, is essential for a comprehensive approach to climate education.

Local initiatives and community-driven solutions are also highlighted as important for fostering grassroots engagement. Programs such as eco-tourism and community awareness campaigns not only address climate issues but also provide economic opportunities for local populations (Ehsan et al., 2021). These initiatives demonstrate the potential for aligning environmental sustainability with economic development, which could serve as a model for other regions. However, the success of these programs is contingent on overcoming the challenges of limited financial resources and adverse environmental conditions (Bacha et al., 2021). The findings emphasize the need for research collaborations and sustained funding to ensure the long-term viability of local environmental initiatives. In conclusion, the thematic analysis offers important insights into the dynamics of climate change education and action, particularly the roles of religious involvement and youth engagement. While the potential for positive change is evident, key challenges such as curriculum development, financial limitations, and the inclusion of marginalized groups must be addressed. Multisectoral collaboration, capacity-building within religious communities, and targeted support for local initiatives are critical for overcoming these barriers and ensuring that climate action efforts are both effective and sustainable.

The policy challenges in Gilgit-Baltistan reflect broader issues observed in other climate-vulnerable regions where national policies often fail to translate into effective local action (Ahmad et al., 2024). Local governance and non-governmental organizations play a crucial role in bridging these gaps by providing community-centered solutions that align with regional socio-economic and environmental realities. However, their effectiveness depends on institutional capacity, financial resources, and the level of coordination between government bodies and non-state actors. Local governance in Gilgit-Baltistan faces significant structural and financial constraints, limiting its ability to implement climate policies tailored to the region's needs (Ahmed and Luqman, 2024). While the Provincial Disaster Management Authority and other local institutions possess contextual knowledge, they often lack financial autonomy and technical expertise, making them reliant on national funding, which is frequently delayed or insufficient. This challenge is not unique to Pakistan. In Nepal's mountainous regions, for instance, local governments have struggled to implement climate adaptation programs due to bureaucratic hurdles and limited financial support from the central government. However, Nepal has made progress by decentralizing climate finance, enabling local municipalities to access international climate funds directly. This approach has empowered local institutions to lead disaster

preparedness initiatives, reforestation programs, and water management projects tailored to their specific environmental challenges (Ahmed et al., 2023).

Non-governmental organizations in Gilgit-Baltistan have played a pivotal role in addressing climate adaptation gaps through community-based initiatives, particularly in areas where government intervention has been weak. Small-scale afforestation projects, water conservation initiatives, and climate education programs have been more effective in raising awareness and building resilience than top-down government policies (Farhan et al., 2022). A similar dynamic is observed in Bangladesh, where local and international NGOs have successfully implemented community-led adaptation programs in flood-prone regions. These initiatives include floating agricultural systems, early warning mechanisms, and sustainable housing projects, which have proven more responsive to community needs than large-scale government policies that often fail to reach marginalized populations. The success of these programs in Bangladesh highlights the potential of collaborative governance models, where NGOs, local governments, and communities work together to design and implement adaptive strategies (Fahad et al., 2023). Despite their effectiveness, NGOs and local governance structures in Gilgit-Baltistan remain fragmented, with limited coordination between different actors. This fragmentation reduces the scalability and sustainability of climate adaptation efforts. In contrast, Kenya's arid and semi-arid lands have demonstrated how structured partnerships between local governments, NGOs, and private stakeholders can improve climate resilience. The Kenya Climate Smart Agriculture Strategy has integrated grassroots knowledge with national policies, ensuring that smallholder farmers benefit from climate-resilient practices supported by both government agencies and development organizations. The Kenyan case illustrates the importance of institutionalized collaboration in scaling up successful adaptation strategies and ensuring their long-term impact (Ergun et al., 2021). A comparative evaluation of these cases suggests that strengthening the role of local governance and integrating NGO efforts into formal policy frameworks can significantly enhance climate adaptation effectiveness in Gilgit-Baltistan. Lessons from Nepal indicate that decentralizing climate finance could empower local authorities, while Bangladesh's experience underscores the effectiveness of community-driven solutions. Kenya's structured partnerships demonstrate the value of institutionalizing collaboration between different stakeholders (Usman et al., 2023a, 2023b). For Gilgit-Baltistan, these insights highlight the need for a multi-tiered governance approach that aligns national policies with localized action, promotes sustainable financing mechanisms, and fosters stronger partnerships between government agencies, NGOs, and community organizations. Without these measures, climate adaptation efforts will remain fragmented and reactive rather than proactive and sustainable.

Conclusion

The bibliometric analysis reveals a fragmented research landscape in Pakistan, particularly regarding climate change, environmental management, and policy. There is a noticeable lack of interdisciplinary collaboration between researchers across various subfields, such as climate science, social sciences, and policy analysis. This fragmentation results in siloed research efforts and

hinders the development of holistic approaches to climate resilience. Moreover, the analysis highlights a regional bias, with most research focusing on more populated provinces like Punjab, Sindh, and Khyber-Pakhtunkhwa, while climate-vulnerable regions like Gilgit-Baltistan receive insufficient attention. This limits the generalizability and applicability of findings to all regions of Pakistan, especially in areas like GB, where specific environmental challenges require focused study. Future research must encourage interdisciplinary approaches and prioritize vulnerable regions like GB to develop comprehensive, context-specific climate strategies.

The analysis identifies significant challenges in translating national climate policies into actionable local strategies, particularly in remote and under-resourced areas like GB. Logistical and administrative challenges, coupled with financial limitations and adverse weather conditions, complicate the implementation of climate action initiatives. To address these challenges, the findings highlight the importance of multisectoral collaboration between religious scholars, educational institutions, NGOs, and local communities. Building trust and fostering partnerships between these stakeholders are crucial for overcoming barriers and ensuring the successful implementation of climate initiatives. Additionally, interdisciplinary collaboration between social and natural sciences is essential for developing comprehensive climate education programs that are relevant to the local context. Effective climate action in GB requires sustained financial and institutional support, as well as the inclusion of marginalized communities in decision-making processes to ensure equitable and inclusive policies.

The findings underscore a significant gap in climate education, particularly among religious leaders and local communities in GB. Despite their academic backgrounds, many religious scholars lack environmental knowledge, which limits their ability to promote climate action effectively. Integrating climate change education into religious teachings, as well as developing region-specific curricula that incorporate local knowledge and practices, is essential for fostering environmental stewardship. Additionally, the project emphasizes the importance of empowering youth through workshops and educational programs. However, for these initiatives to be effective, they must be sustained and address systemic barriers such as unemployment and limited resources. Structured educational programs that focus on climate awareness and practical skills are crucial for preparing local populations in GB to adapt to and mitigate climate risks.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

The studies involving humans were approved by the Ethical Review Board Committee of University of Baltistan. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FF: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. SabA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. HR: Resources, Software, Writing – review & editing. FS: Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. SalA: Data curation, Formal analysis, Funding acquisition, Resources, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2025.1527694/full#supplementary-material

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