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Mapping analytical hierarchy process research to sustainable development goals: Bibliometric and social network analysis

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A R T I C L E I N F O

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A B S T R A C T

The drive to achieve the Sustainable Development Goals (SDGs) becomes more urgent as the 2030 deadline draws near, increasing research in various sectors. Nevertheless, studies that systematically map Analytical Hierarchy Process (AHP) publications with the SDGs need to be more conspicuously lacking. Our study adds a new perspective to the field by creatively bridging this knowledge gap using the Elsevier SDG Mapping Initiative. To find research clusters, trends, and themes linked to SDGs and their connection to environmental sustainability, we thoroughly analyzed 29,897 publications from 2012 to 2022. The analysis showed that SDG 15, SDG 7, SDG 12, SDG 13, and SDG 11 were the top five SDGs, with an environmental focus among the 17 SDGs. These top SDGs had many clusters connected to them, illustrating various sustainability-related problems. The study also looked at connections between SDGs, the nations with the highest rates of productivity, the top contributors, and the journals with the highest citation counts. We discovered three separate SDG clusters using co-occurrence network analysis, each representing a different SDG. We discovered relevant SDGs using Matrice d'impacts croisés multiplication appliquée á un classment (MICMAC) analysis and centrality indicators like eigenvector and betweenness. This novel method for publishing analysis combines an AHP focus that aligns with the SDGs with social network analysis and centrality metrics. Our research advances knowledge of how the AHP technique can assess initiatives supporting the SDGs. We offer essential insights into prioritizing sustainable development measures by identifying research clusters, trends, and issues related to environmental sustainability. This study highlights the subject's most important SDGs, productive nations, helpful organizations, and significant journals.

1. Introduction

The Analytic Hierarchy Process (AHP) is a widely employed method for addressing intricate problems involving multiple criteria. AHP constitutes a systematic and structured approach to decision-making, wherein options are ranked and compared based on various criteria. Thomas Saaty developed this method during the 1970s [1]. AHP encompasses three fundamental components: a pairwise comparison of criteria, a hierarchy of objectives, and an eigenvector computation for determining the relative significance of the

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alternatives [2]. The pairwise comparison delineates the relative importance of each criterion within the hierarchy, while the hierarchy of objectives dissects the decision-making issue into smaller, more manageable segments [2]. Subsequently, the pairwise comparisons are integrated with the eigenvector calculation to yield a final ranking of the alternatives according to their relative priority [3].

AHP has been extensively utilized across various sectors, such as engineering [4], management [5], public policy [6], and environmental studies [7], among others. The benefits of AHP encompass its ability to handle various criteria, its transparency and structure, and its capability to integrate subjective preferences and opinions of decision-makers into the decision-making process [1]. However, AHP also possesses limitations, including the requirement for a well-structured hierarchy of objectives and dependence on subjective judgments [8]. Despite these shortcomings, researchers and practitioners frequently employ AHP as a primary method for decision-making, continuously refining it through ongoing research and development [8].

The growing utilization of the AHP in academic research in recent years is worth studying to understand its potential in addressing United Nations (UN) Sustainable Development Goals (SDGs). Established in 2015, the SDGs serve as a global call to action to eradicate poverty, safeguard the environment, and ensure prosperity and peace for all [9]. In 2012, the United Nations Conference on Sustainable Development (Rio+20) generated a document that provided feasible measures for implementing sustainable development two decades after the "Earth Summit" held in Rio de Janeiro in 1992. To expand on the achievements of the Millennium Development Goals (MDGs) and to correspond with the post-2015 development strategy, the conference's member nations agreed to initiate a procedure to establish a set of SDGs. Sustainable development challenges comprehension and implementation with its multiple definitions and complex interplay of variable systems. Likewise, "sustainability" is difficult to define due to its varying interpretations across disciplines [10]. Despite these complexities, sustainable development is commonly linked to the "triple bottom line" concept, which emphasizes the balance of economic, social, and environmental factors [11,12]. AHP offers a systematic decision-making approach, which can aid organizations and governments in prioritizing and allocating resources to support the achievement of the SDGs. As such, analyzing the extent to which research articles on AHP map to the SDGs is valuable in understanding the practical applications and potential impact of AHP on sustainable development.

The SDGs of the United Nations offer a global framework for tackling the most critical social, economic, and environmental issues [13]. Because of this, there is increasing interest in using the AHP to assess and rank actions that help achieve the SDGs. To add to this crucial and timely field of research, we have decided to explore the SDG angle in our AHP research in this paper. The SDGs offer a vital framework for tackling global issues, and it is crucial to research how to use the AHP methodology to assess actions that advance the SDGs.

Numerous SDGs emphasize the sustainable utilization and management of natural resources, preservation of biodiversity, reduction of pollution, and mitigation of climate change impacts, categorizing them within the environmental domain. The following SDGs are examples of those that belong to the environmental category [14,15].

- SDG 6 (Clean Water and Sanitation) targets providing sustainable water and sanitation management for all.
- SDG 7 (Affordable and Clean Energy) aspires to ensure access to affordable, reliable, and sustainable clean energy for everyone.
- SDG 11 (Sustainable Cities and Communities) works towards building inclusive, safe, resilient, and sustainable cities and communities.
- SDG 12 (Responsible Consumption and Production) encourages sustainable consumption and production practices.
- SDG 13 (Climate Action) demands urgent action to combat climate change and its repercussions.
- SDG 14 (Life Below Water) conserves and uses oceans, seas, and marine resources for sustainable development.
- SDG 15 (Life on Land) is dedicated to protecting and promoting the sustainable use of terrestrial ecosystems, managing forests responsibly, combating desertification, and halting biodiversity loss.

These SDGs highlight the crucial role that environmental sustainability plays in achieving sustainable development and addressing the interrelated problems of "climate change," "resource depletion," and "ecosystem degradation" [16,17].

The Analytic Hierarchy Process (AHP) adaptability has enabled its application across various fields, such as renewable energy sources, environmental impact analysis, sustainable manufacturing practices, and green public procurement. The growing focus on sustainable development concerns has driven this increased usage. Researchers have documented the effectiveness of AHP in numerous studies, showcasing its potential to address sustainability challenges. The following discussion will look at AHP-related research in sustainable development settings.

Ahmad and Tahar [18] aimed to develop an assessment model using AHP to select renewable energy options by examining the potential of different renewable resources. The model illustrated that each resource was biased toward a specific criterion: solar was biased toward economics, biomass was biased toward social issues, hydropower was biased toward technical matters, and wind was biased toward environmental issues. Electricity availability is crucial for the growth of the national economy and society. Ren et al. [19] used a multi-criteria decision analysis (MCDA) framework to evaluate the reliability and security of energy supply, incorporating nine metrics across four dimensions - "availability and supply security," "affordability and dependability," "energy and economic efficiency," and "environmental stewardship."

Environmental impact assessment (EIA) is an inherently complex, multi-dimensional process involving various actors and criteria. Multi-criteria techniques, such as AHP, can be valuable decision aids for performing EIA. Ramanathan [20] suggested that AHP could effectively address this need. Using AHP helped authorities prioritize their environmental management plan and allocate the budget for mitigating adverse socio-economic impacts by capturing stakeholders' understanding of the relative severity of various socio-economic effects. Ananda and Herath [21] aimed to evaluate AHP's potential for integrating stakeholder preferences into regional forest management. The findings demonstrated that AHP could enhance the process's transparency and legitimacy while formalizing public input into decision-making.

Gupta et al. [22] introduced the AHP manufacturing sustainability model, encompassing several manufacturing techniques. In the early stages of this project, the researchers surveyed academia and industry to construct an AHP model. A sustainability consultant recommended that the electrical panel sector implement sustainable production techniques to stay competitive. Kolotzek et al. [23] described a model for evaluating raw materials and providing sustainable decision support, suggesting that businesses apply it within their operations. Ahsan and Rahman [24] investigated barriers to green public procurement implementation in the public health sector, developing a framework for green public procurement implementation based on a comprehensive literature review, including five difficulty categories and sixteen barriers. Promentilla et al. [25] proposed that a stochastic fuzzy AHP decision model addresses the complexities and uncertainties in selecting clean technologies, framing the problem as a multi-criteria decision-making model based on AHP. Due to AHP's capability to help decision-makers prioritize and assess risk factors, its use in risk management has attracted much attention. The study by Esfandabadi et al. [26] significantly contributes to comprehensive motor insurance management. The study investigates how risk-level characteristics unique to the field of vehicle insurance might be prioritized using AHP. The study shows how a thorough assessment of risk factors is made possible by the hybrid multi-criteria decision-making model used in the study, supporting efficient decision-making in insurance management. The authors include AHP to offer insights into the decision-making process and helpful suggestions for enhancing risk management tactics in the vehicle insurance sector.

The drive to achieve the Sustainable Development Goals (SDGs) becomes more urgent as the 2030 deadline draws near, increasing research in various sectors. Nevertheless, studies that systematically link AHP publications with the SDGs are conspicuously lacking. Our study adds a new perspective to the field by creatively bridging this knowledge gap using the Elsevier SDG Mapping Initiative [27]. We have listed some initiatives that map research articles to the SDGs.

- The SDG-queries initiative from Aurora-Network-Global (https://github.com/Aurora-Network-Global/sdg-queries) aims to map research on sustainable development by offering a comprehensive set of queries to examine research outputs.
- An initiative to map out sustainable development research is presented in the study "Contextualising Sustainable Development Research" (https://digitalscience.figshare.com/articles/report/Contextualizing_Sustainable_Development_Research/12200081). By examining the subject environment, collaboration trends, and funding sources; it aids stakeholders in identifying research gaps and openings in the area.
- The University of Auckland's SDG Mapping initiative (https://www.sdgmapping.auckland.ac.nz/) strives to illustrate the connection between research results and the SDGs. It offers an interactive platform where users can investigate the effects of research initiatives on certain SDGs, promoting collaboration and enabling well-informed decision-making in pursuing sustainable development goals.
- A program called STRINGS (Sustainable Development Goals Indicator worldwide Registry and INdex System) (http://strings.org.uk) aims to map and track the SDGs' development globally.

The primary objective of this study is to conduct a bibliometric analysis of publications related to AHP and their alignment with sustainable development goals, aiming to identify existing gaps and suggest potential future research directions. By examining the 29,000+ total publications (TP) and explicitly focusing on the 10,000+ mapped to the SDGs, this study introduces a novel approach to bibliometric analysis within the field. Furthermore, incorporating social network analysis and centrality measures [28] in analyzing the SDG-mapped AHP publications contributes additional novelty to the approach. This study has determined the following research questions (RQs).

- RQ1: How has the volume of AHP publications evolved, and what trends can be observed in the context of sustainable development goals? Which countries, journals, and institutions are the leading contributors to AHP research aligned with the SDGs, and how do their collaborations and networks shape the research landscape?
- RQ2: What are the primary research themes and topics in AHP literature related to sustainable development goals, and how do they interconnect?
- RQ3: How does the application of social network analysis and centrality measures enhance the understanding of the AHP research landscape about SDG?

2. Research methodology

Our research utilized a reliable collection of peer-reviewed papers from the *dimensions database*, which underwent quantitative statistical analysis [29]. Multiple scholarly studies have confirmed the validity of the dimensions database [30]. Science mapping tools are an essential part of bibliometrics, and one of the most commonly used citation-based approaches is bibliographic coupling [27,31]. This approach is valuable for monitoring current research trends and identifying emerging study topics [32–35]. This approach's forward-looking nature makes it ideal for identifying new patterns in a particular area [36,37]. The study utilized country and journal bibliographies to evaluate the similarity of cited articles [38,39]. This study also looked into social network analysis. The actors and the relationships in a given setting are the two main themes of social network analysis, which aims to comprehend networks and their participants [40,41]. The visualizing application VOSviewer, widely used for science mapping purposes, was employed [42–46].

Bibliometric and social network analysis has recently gained popularity and is valuable for identifying new study topics in a particular field. Additionally, social network analysis directs researchers by analyzing numerous dynamics for future research direction by identifying the most important researchers, encouraging researcher collaboration, and identifying new trends in the study field [47]. Social network analysis (SNA) is used to find these gaps and investigate prospective research areas in the future. The primary objective is the widespread adoption of SNA as a concept and a methodology. It is crucial to differentiate between the keywords "Social Network Analysis" and "Network Analysis" without the "social." Although primarily focusing on network analysis, some publications still need to include the complete phrase for SNA [48]. By examining the network connections represented by the nodes and ties, SNA is a reasonably standardized analysis method in social relations and structure [49]. In our research of the SDG network, we utilize two metrics of centrality frequently used in social network analysis (SNA): betweenness and eigenvector [50]. To see if the analysis would yield different results, we also use an experimental metric called "MICMAC" that examines the level of exposure (the degree to which other factors upstream are likely to shift the factor) and influence (the degree to which the factor shifts other factors downstream) for each element. The importance of an SDG node as a connecting point for information flow in the network was evaluated using betweenness centrality. The amount of times a node is on the shortest path between two other SDG nodes is determined by this measure. High betweenness centrality SDG nodes serve as vital connectors between diverse network segments. While considering the centrality of the nodes it is connected to, Eigenvector centrality gauges a node's influence within the network. This statistic considers a node's connectivity and the centrality of its connected nodes. It implies that the number of crucial nodes connected to a node determines its significance. High eigenvector centrality nodes in SDG networks are essential focal points. We derive centrality measurement using the SDG toolkit [51]. Grandjean's [52] use of SNA for Twitter data and Emrouznejad and Marra's [47] application to research the Analytic Hierarchy Process serve as examples of how SNA has been successful in bibliometric studies. In our research, SNA was employed for the first time in tying AHP to SDGs.

To begin with, we have structured our research to describe the systematic literature review procedure. The results section discusses the overall research performance and evolution of SDGs, productive countries, top-contributing institutions, and cited journals. In addition, we use a keyword co-occurrence network analysis to find links and relationships among various keywords used in the

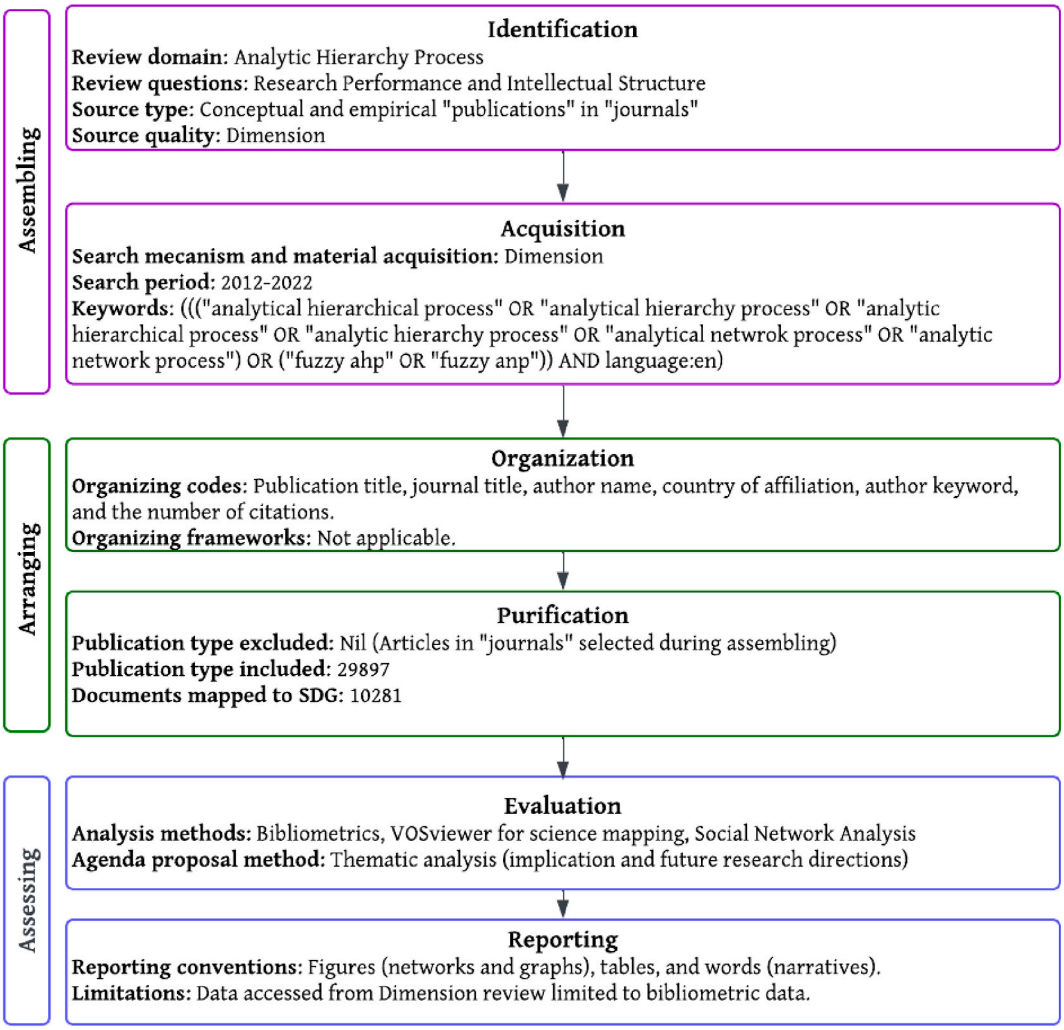

Fig. 1. SPAR-4-SLR protocol framework [53].

literature. This study enables us to recognize the key ideas and concepts regularly discussed in connection with the SDGs. By illustrating the network, we can better grasp the interactions and interdependencies between cluster themes. In addition, we use social network analysis methods to investigate the links and patterns in the sustainable development field. We identify key players and hubs in the network using metrics like eigenvector centrality and betweenness. In addition, we use the MICMAC cross-impact analysis to evaluate the causal connections and effects between various social network components. The study's conclusions are discussed in the final section, emphasizing its limitations.

2.1. SPAR-4-SLR protocol

The study employed the SPAR-4-SLR techniques developed by Paul et al. [53] to conduct the bibliometric analysis of AHP publications and citations. Fig. 1 highlights the methodology used in each process stage to direct assessing, arranging, and assembling duties.

2.1.1. Assembling

The first step in the process involves collecting publications for analysis, known as assembling. In this study, the Dimensions database was utilized in February 2023 to search for publications that included AHP and its associated terms. Relevant keywords, titles, and abstracts were used as part of the search parameters. Researchers retrieved 29,897 publications from 2012 to 2022, of which 10,281 were mapped to SDGs. Our decision to use the Elsevier SDG Mapping Initiative [27] is based on how well its Science-Metrix group directly integrates with the Dimension database's search criteria. The project uses 17 SDG queries to link articles to the relevant SDGs. Each SDG's specific aims and sub-targets have been carefully considered in developing these questions. Further precision is attained through careful evaluation and input from professionals and academics. A machine learning model was then added to these queries to ensure the accuracy remained over 80%. Through the provision of pre-set search terms for each SDG, the Dimension database streamlines the research process [54].

2.1.2. Arranging

The next step, arranging, involves organizing and refining the articles through inclusion and exclusion criteria. Several pieces of information, such as the journal title, author name, publication title, country of affiliation, total publications (TP), and total citations (TC), were used as codes to categorize the search data of publications. These codes facilitated the organization and examination of the data in a more structured and systematic manner. The filtering process did not exclude any journals.

2.1.3. Assessing

The study's final stage involves assessment, including evaluation and reporting. The evaluation section of the article encompasses an overview of the analysis method and the study's limitations. VOSviewer was the primary software used for evaluation and trend analysis. Since the review was based on secondary data that is publicly available through Dimensions, no ethics approval was necessary.

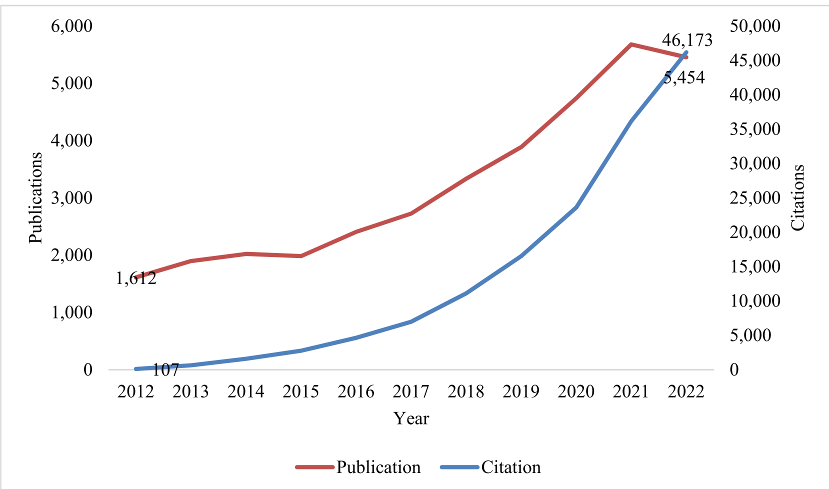

Fig. 2. Trends of citations and publications.

3. Results and discussion

3.1. Research performance and evolution SDGs

Fig. 2 presents the total publications and citations retrieved. The total number of publications and citations recovered over time is shown in Fig. 2. A line graph showing the total number of publications and citations each year is shown for works related to AHP. The graph's rising slopes represent the expansion rate of publications and citations in the literature on AHP. The researchers examined the publication patterns in the AHP literature using the data they collected on total publications (TP) and citations (TC). The findings show a yearly increase in both citations and publications. In 2022, researchers received the most citations (TC = 46,173) from publications (TP = 5454). These results demonstrate that 2021 was a particularly productive year in terms of publication for AHP research.

The evolution of the SDGs based on research productivity (publications) and research impact (citations) is shown in Fig. 3. A quadrant chart, sometimes called a scatter plot or XY chart, provides the visual depiction of data points drawn on a two-dimensional plane. The x-axis, in this instance, shows total publications (TP), which reflects the total amount of research done, and the y-axis represents total citations (TC), which represents the influence and impact of that study. Researchers can acquire insights into the research productivity and influence connected with particular SDGs by grouping data points into various quadrants depending on their TP and TC values. The top five SDGs are SDG 15, SDG 7, SDG 12, SDG 13, and SDG 11, and they belong to the "environment" group of SDGs.

The data points in the high research influence quadrant correspond to research with many citations (TC) but few publications (TP) as their sources. These data point to a high level of research influence, indicating that a small number of influential studies have attracted much interest from other researchers. Research in this area can affect policy choices and bring about significant change. SDG 13 and SDG 12 fall under this quadrant. Studies with high TC and numerous publications (TP) are indicated by data points in the high research productivity and influence quadrant. High research output and influence are represented in this quadrant, which reflects the overall influence of many studies. Multiple articles routinely produce high levels of attention and impact, indicating a broad and ongoing effort in this research sector. SDGs 15 and 7 falls under this quadrant. Data points within the high research productivity quadrant correspond to studies with a high publication count (TP) but a low citation count (TC). A significant amount of research has been produced in this quadrant, which denotes strong research production. Even though these studies might not have gotten much notice or acclaim, they still advance our knowledge and comprehension of the subject. SDG 11 falls under this quadrant.

3.2. Productive countries and their SDG mappings

A quadrant chart, sometimes called a scatter plot or XY chart, provides the visual depiction of data points drawn on a two-dimensional plane. The x-axis, in this instance, shows total publications (TP), which reflects the total amount of research done, and the y-axis represents total citations (TC), which represents the influence and impact of that study. Researchers can acquire insights into the research productivity and influence connected with particular productive countries by grouping data points into various quadrants depending on their TP and TC values. Fig. 4 demonstrates that China is the only country with high research productivity and influence categories. On the other hand, India and Iran fall under the high research influence category.

The nations with the most contributions mapped to SDGs include China, India, Iran, Turkey, the United States, Indonesia, the

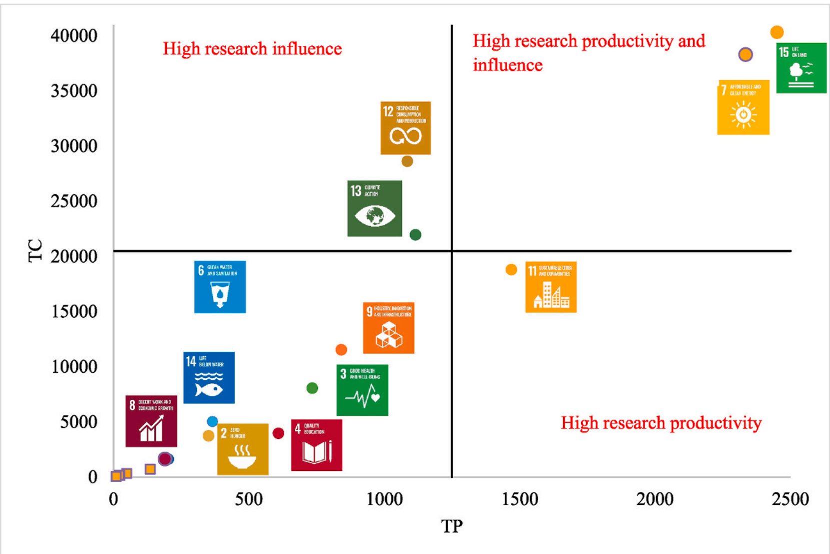

Fig. 3. Evolution of SDGs.

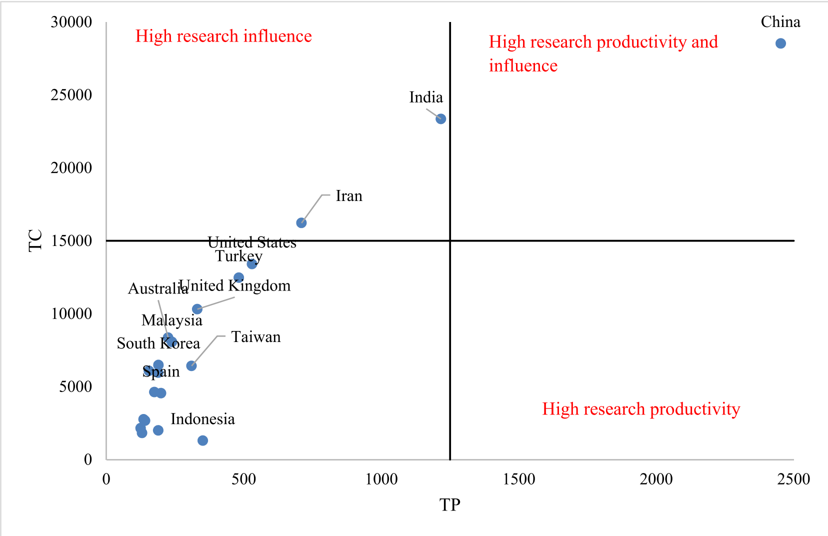

Fig. 4. Productive countries.

United Kingdom, Taiwan, Malaysia, and Australia. Fig. 5 depicts China, India, and Iran as the top three most productive countries contributing to the SDGs. China contributed more significantly to SDG 7, while India and Iran contributed more substantially to SDG 15.

3.3. Top Contributing Institutions and their SDG mappings

Fig. 6 displays the top-contributing institutions in AHP research. The University of Tehran emerges as the most productive and influential research institution, contributing the most to the field. Indian Institute of Technology Roorkee and the University of Technology Malaysia demonstrate high research influence. North China Electric Power University and State Grid Corporation of China also exhibit high research productivity.

Fig. 7 illustrates that the University of Tehran has the highest number of SDG-mapped publications, with SDG 15 being the most prominent. SDG 7 and SDG 15 are the SDGs most commonly mapped by the top-contributing institutions. The leading institutions identified by the SDGs include North China Electric Power University and State Grid Corporation of China. Both institutions made significant contributions to SDG 7—affordable and sustainable energy.

3.4. Top cited journals and their SDG mappings

Researchers can acquire insights into the research productivity and influence connected with particularly cited journals by grouping data points into various quadrants depending on their TP and TC values. Fig. 8 shows the top cited journals led by the Journal of Cleaner Production, which boasts high research influence and sustainability and has the highest research productivity and influence.

Fig. 9 highlights that Sustainability and the Journal of Cleaner Production are the top two journals significantly contributing to achieving the SDGs. These journals have substantially contributed to the top five SDGs, including SDG 15, SDG 7, SDG 11, SDG 12, and SDG 13. Notably, the Sustainability journal has made a more significant contribution towards SDG 11, which emphasizes making cities and human settlements inclusive, safe, resilient, and sustainable. In contrast, the Journal of Cleaner Production has made a more substantial contribution towards SDG 12, which focuses on ensuring sustainable consumption and production patterns. These journals have played a crucial role in promoting sustainability research and furthering the advancement of the SDGs.

3.5. Keyword Co-occurrence network

Keyword co-occurrence analysis is utilized to analyze further each of the top five SDGs identified in the network. This approach allows for examining the most common keywords with each SDG, which can provide insights into the main themes and topics associated with each goal. By analyzing keywords' co-occurrence, a deeper understanding of the research trends and priorities within each SDG cluster can be gained.

The keyword co-occurrence network analysis helps identify clusters of the top SDGs and understand their interlinkages. In this context, a cluster refers to a group of SDGs with a high degree of co-occurrence or co-occurrence frequency. Fig. 10 displays the SDG network based on the citation data, revealing three distinct clusters of SDGs. Cluster 1 comprises SDGs 12, 11, 9, 1, 5, 10, 16, 3, and 8; Cluster 2 comprises SDGs 15, 6, and 2; and Cluster 3 encompasses SDGs 7 and 13. Among the three clusters, the link between SDG 7 and SDG 13 is the strongest, as indicated by the thickness of the connecting line. The circle size surrounding each SDG represents the

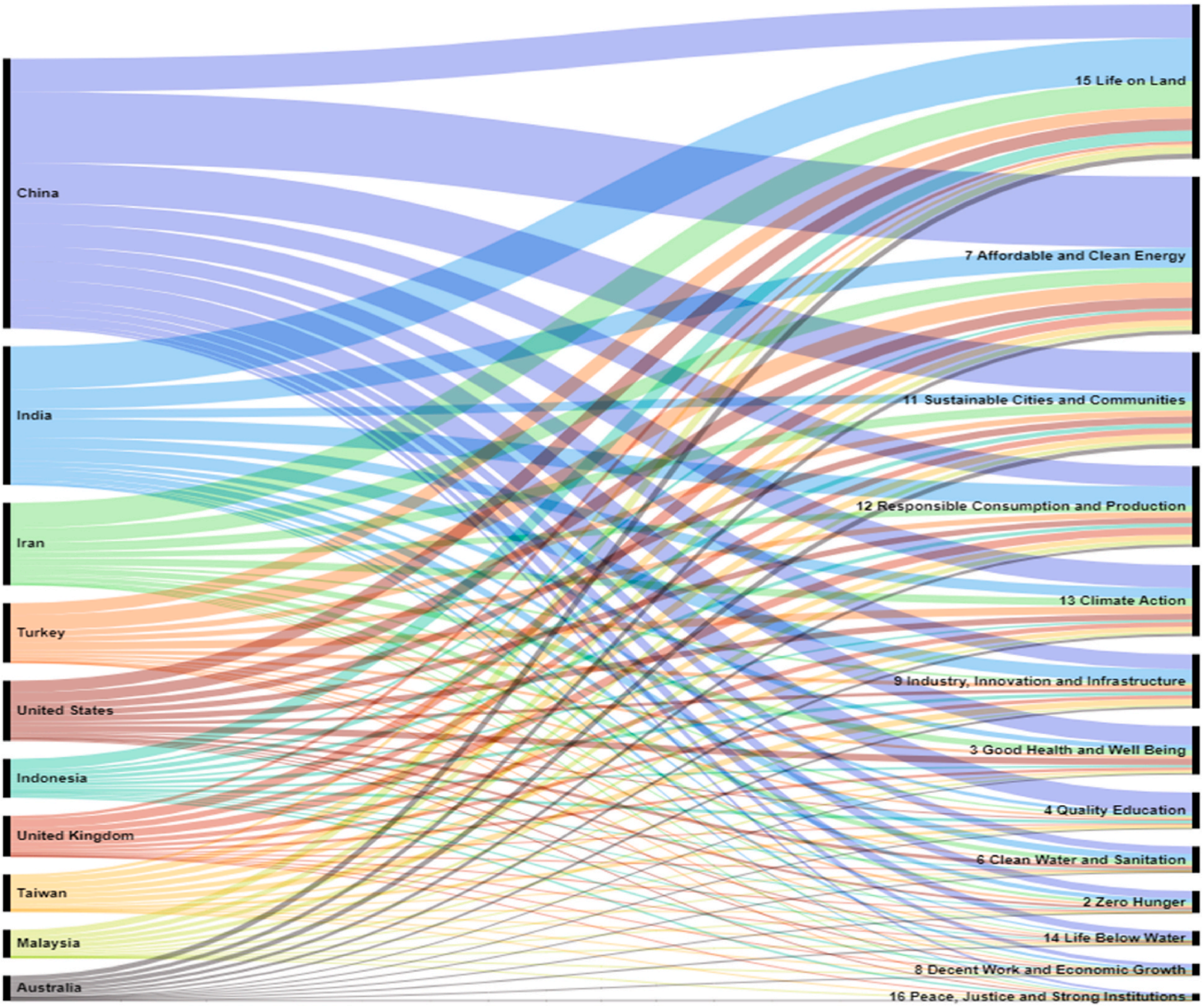

Fig. 5. Productive Countries and their SDG mappings.

number of citations received.

The environment group concentrates on protecting and preserving the Earth's ecosystems, encouraging sustainable resource management, and reducing the effects of climate change within the broad range of SDGs. It is essential to recognize and comprehend the key themes and clusters linked to the top five SDGs for the environment to solve these problems effectively. The cluster themes for each of these SDGs are summarised in Table 1, which offers important insights into the many areas of attention for each goal.

These clusters show the multifaceted nature of environmental sustainability by illustrating the various fields of research and implementation under each goal. These clusters provide invaluable insights into the methods and approaches used to achieve the various SDGs, from utilizing cutting-edge decision-making methodologies to assessing renewable energy options and promoting resilient communities. The following subsections provide a detailed analysis of the keyword co-occurrence network for each "environment" group SDG.

3.5.1. SDG 15 (life on land)

Fig. 11 shows the keyword co-occurrence network of SDG15-mapped publications.

A keyword co-occurrence network is an effective analytical technique that graphically depicts the associations between keywords in a given context. This network offers insights into the most popular and important terms by employing circle size to denote importance. The separation between these circles reveals how closely related the terms are. Based on these keywords in Fig. 11, 5 cluster themes emerged. Table 2 shows the five cluster themes and keywords in each cluster formed based on SDG 15 mappings.

1) ***AHP for life on land*** - Applying AHP in protecting life on land is essential in prioritizing actions and interventions that significantly impact biodiversity conservation and reducing threats to ecosystems and species that depend on them. By utilizing AHP, we can

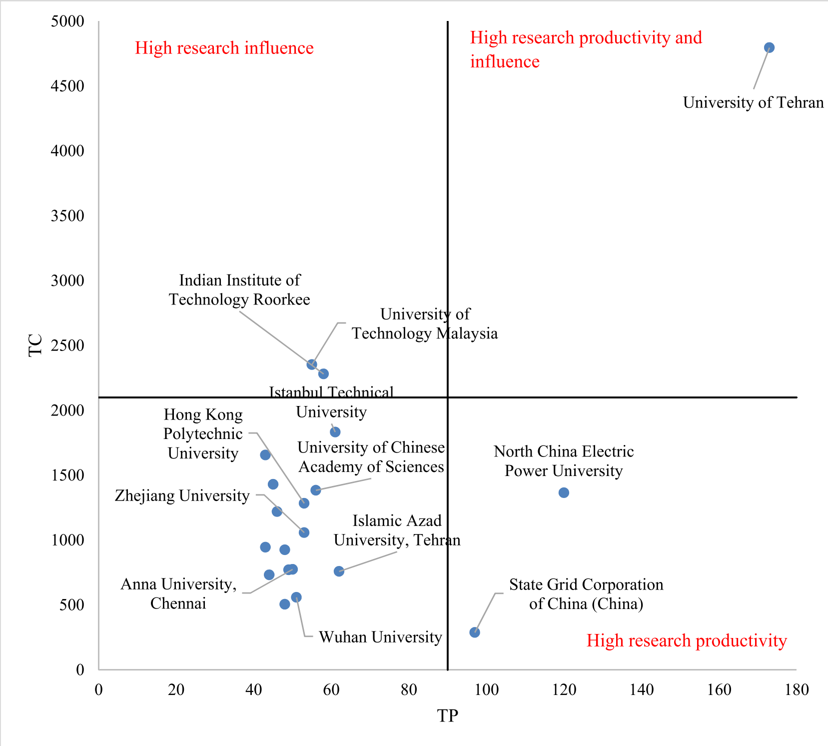

Fig. 6. Top contributing institutions.

focus on the most effective and efficient interventions to conserve biodiversity and sustain ecosystems for future generations. Al Garni and Awasthi [55] study aimed to evaluate and select the best location for utility-scale solar PV plants using GIS and an MCDM technique, considering various economic and technical factors to ensure maximum power while minimizing project expenses.

2) ***Natural hazard mapping and risk assessment*** - AHP can be used in natural hazard susceptibility mapping and risk assessment, which is essential for disaster risk reduction and management. AHP helps develop susceptibility maps that show areas more likely to be affected by natural hazards. Ouma and Tateishi [56] utilize an integrated AHP and GIS analysis technique to model and predict the size of flood risk zones.
3) ***AHP for ecosystem conservation and restoration*** - MCDA has been employed as a valuable method to enhance managerial skills in ecosystem conservation and restoration. Rahmati et al. [57] used a conventional methodology to identify possible zonation of groundwater resources using combined AHP, GIS, and remote sensing. This approach helps address the worldwide shortage of groundwater due to misuse and observable weather changes.
4) ***AHP, GIS, and fuzzy logic for land use assessment and decision-making*** - Combining AHP, GIS, and fuzzy logic is a practical method for analyzing land usage and making wise decisions to protect the environment and human life. This integration allows for a thorough examination of different aspects influencing land use decisions. Sánchez-Lozano et al. [58] study combines GIS and MCDM methodologies to assess the best location for “photovoltaic solar power plants."
5) ***MCDM approaches for restoring degraded land*** - MCDM methods are powerful techniques for rehabilitating degraded land. Decision-makers can identify and assess several restoration solutions based on various criteria and objectives using MCDM methodologies. This strategy enables decision-makers to make well-informed choices considering multiple criteria and goals, resulting in more successful and long-lasting restoration initiatives. Kayastha et al. [59] highlight the need for systematic landslide studies, including inventory mapping and risk assessment, in managing landslide-prone regions in Nepal.

3.5.2. SDG 7 (Affordable and Clean Energy)

Fig. 12 shows the keyword co-occurrence network of SDG 7 mapped publications.

This network offers insights into the most popular and important terms by employing circle size to denote importance. The separation between these circles reveals how closely related the terms are. Based on these keywords in Fig. 12, 3 cluster themes emerged. Table 3 shows the three cluster themes and keywords in each cluster formed based on SDG mappings.

1) ***MCDM approach for energy utilization: AHP and Fuzzy AHP*** - MCDM techniques like AHP and Fuzzy AHP are useful for optimizing energy utilization and transmission in SDG 7. Choudhary and Shankar [60] suggest an evaluation and selection strategy for the ideal location of thermal power plants using STEEP-fuzzy AHP-TOPSIS, which promotes sustainable decision-making in

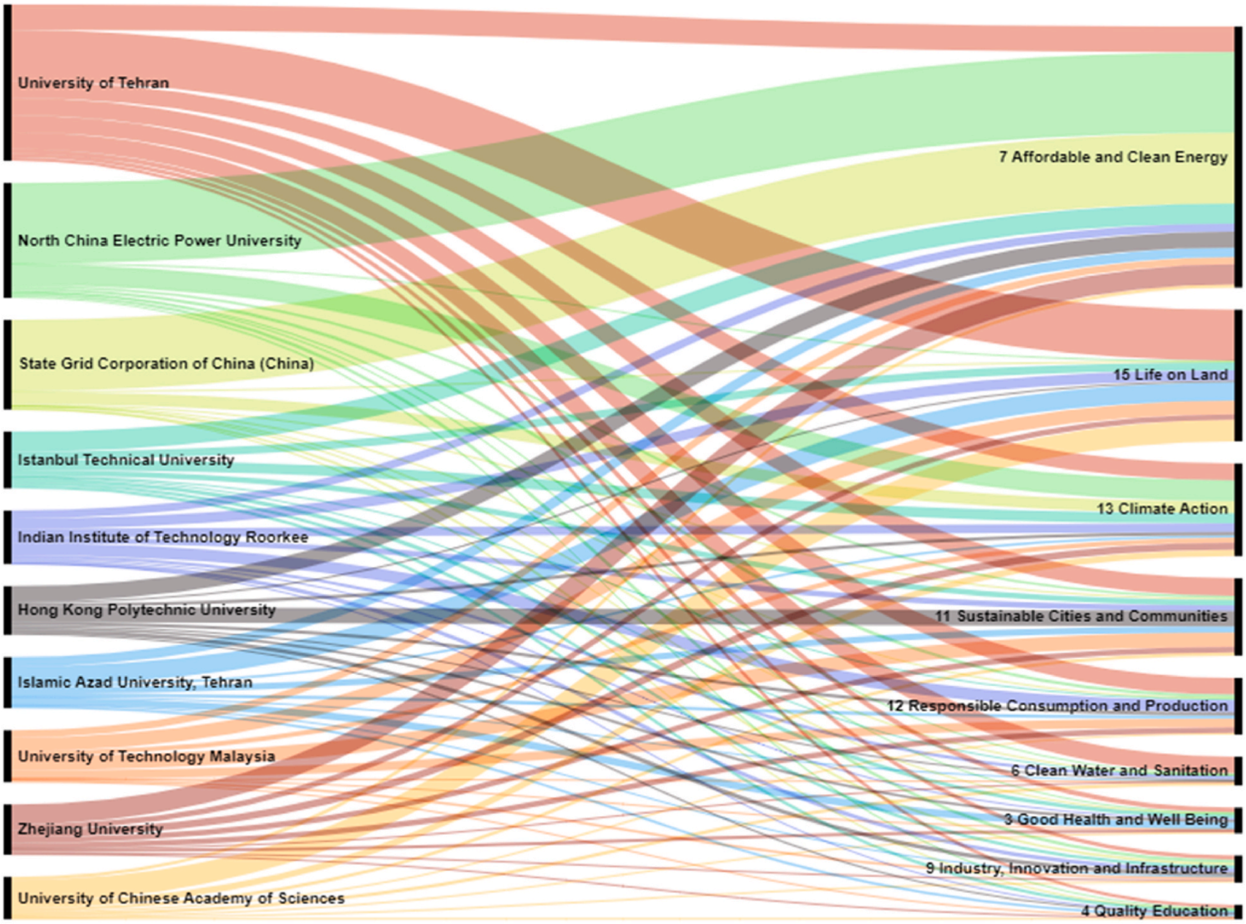

Fig. 7. Top Contributing Institutions and their SDG mappings.

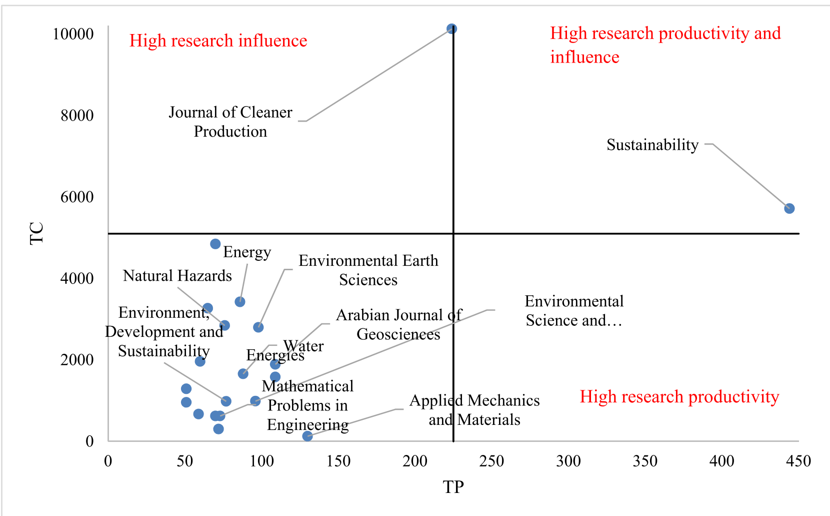

Fig. 8. Top cited journals.

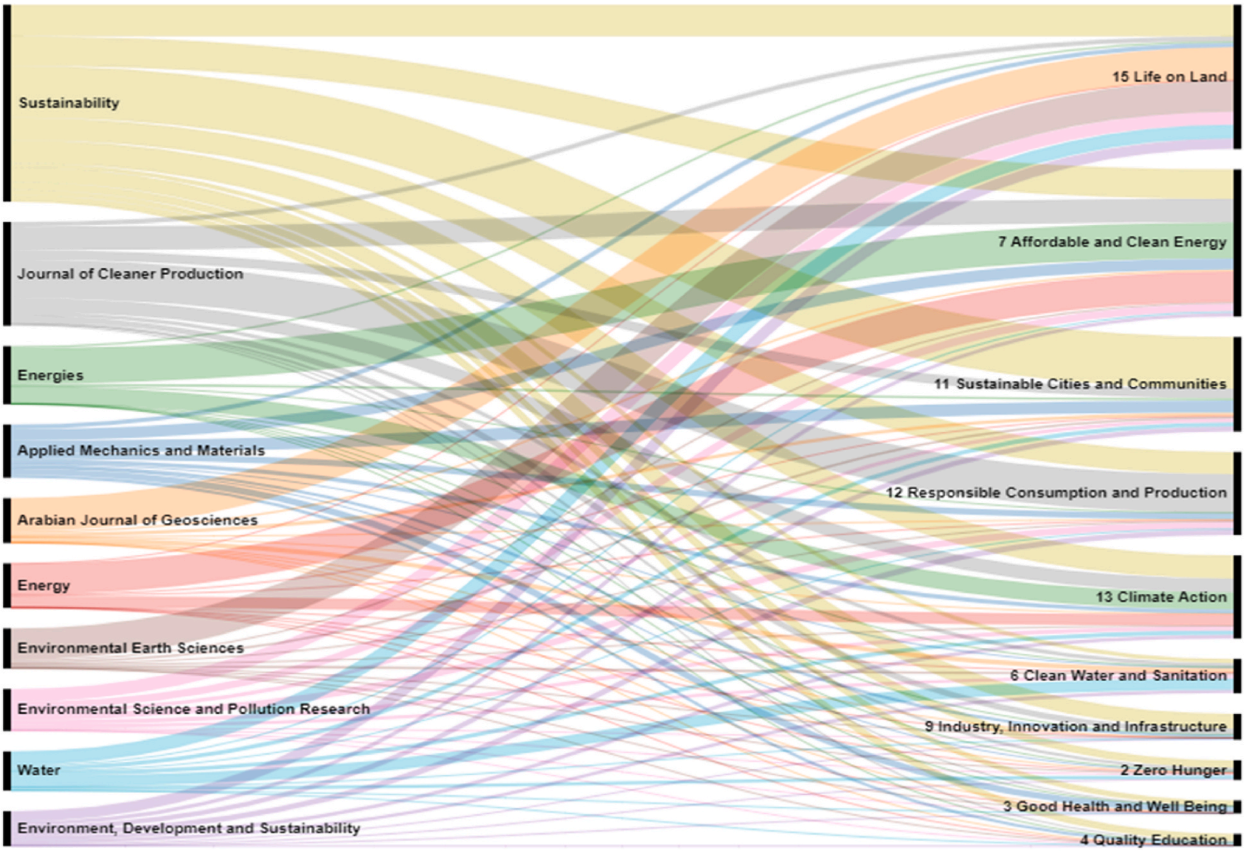

Fig. 9. Top-Cited Journals and their SDG mappings.

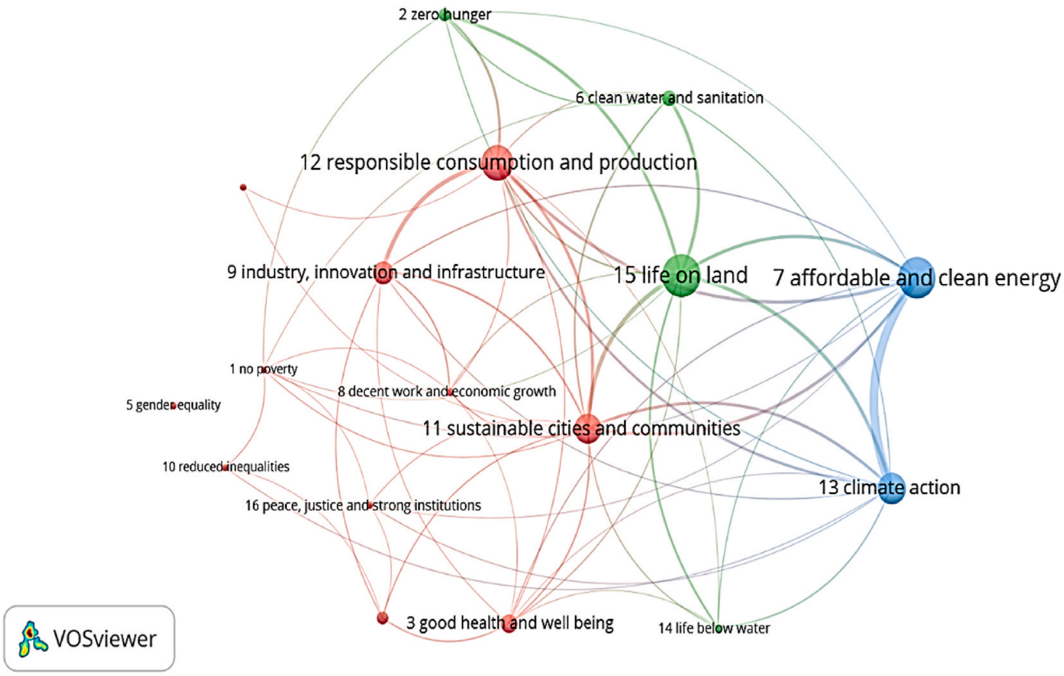

Fig. 10. SDG network based on AHP publications.

Table 1
Cluster themes based on five SDGs.

SDG	Number of clusters	Cluster themes
SDG 15 (Life on Land)	5	1. AHP for life on land 2. Natural hazard mapping and risk assessment 3. AHP for ecosystem conservation and restoration 4. AHP, Geographic Information System (GIS), and fuzzy logic for land use assessment and decision-making 5. Multi-Criteria Decision Making (MCDM) approaches for restoring degraded land
SDG 7 (Affordable and Clean Energy)	3	1. MCDM approach for energy utilization: AHP and Fuzzy AHP 2. Multi-criteria and Sensitivity analysis for energy policy implications 3. Use of AHP for affordable, clean, and modern energy
SDG 12 (Responsible Consumption and Production)	3	1. Sustainable supplier selection using MCDM in supply chain management 2. MCDM techniques for circular supply chain management 3. Overcoming barriers for sustainable supplier selection: MCDM technique
SDG 13 (Climate Action)	4	1. MCD approaches for climate action 2. AHP for integrating climate change measures 3. Renewable energy evaluation for climate protection 4. AHP and GIS for climate risk assessment
SDG 11 (Sustainable Cities and Communities)	5	1. AHP application for sustainable communities 2. Risk assessment for natural disasters 3. AHP for green and resilient buildings 4. Fuzzy AHP for socio-economic-environmental protection 5. Application of GIS for waste management

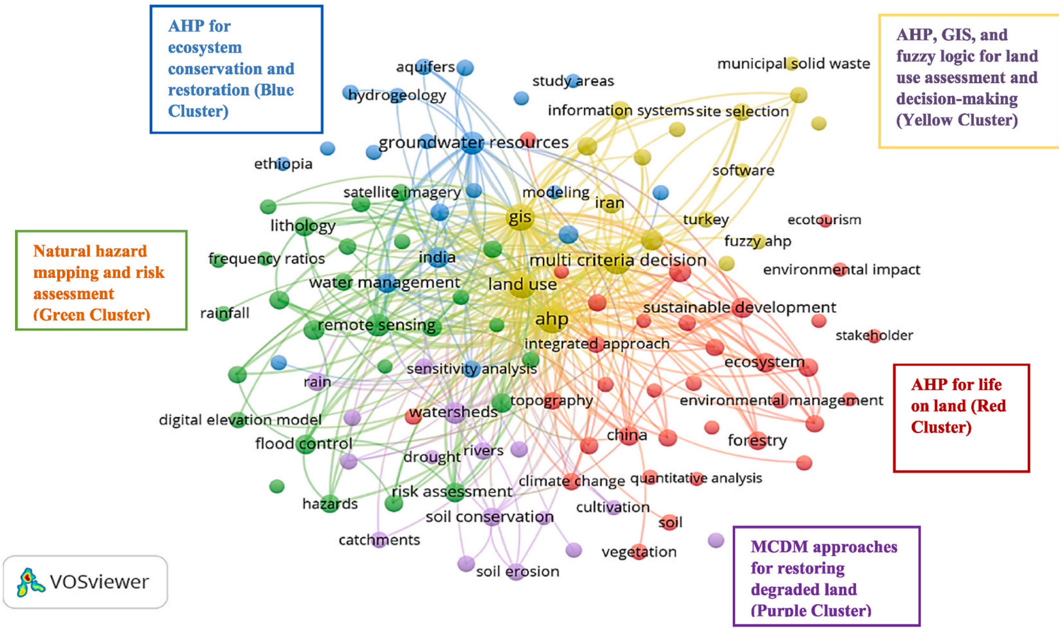

Fig. 11. Keyword co-occurrence network of SDG 15.

resolving energy concerns and analyzing conflicting effects. Siksnelyte et al. [61] provide an overview of how decision-making techniques address difficulties in developing sustainable energy sources.<abstractend>

2) ***Multi-criteria and Sensitivity analysis for energy policy implications*** - Multi-criteria (MCA) and sensitivity analyses are valuable tools for addressing energy policy implications. By considering multiple criteria and testing the Sensitivity of decisions to changes in input parameters, policymakers can identify robust and optimal solutions to energy-related problems. Bohra et al. [62] discuss using MCDM in various energy-related fields, while Effatpanah et al. [63] describe and apply five well-known MCDM methods in determining energy technologies.
3) ***Use of AHP for affordable, clean, and modern energy*** - AHP can be used to prioritize and evaluate different options for achieving affordable, clean, and modern energy. Focusing on energy education and awareness programs emphasizing sustainable behaviors and structures is necessary for advancing toward a more sustainable energy future. Ilham et al. [64] investigated and assessed the

Table 2
SDG 15 Cluster themes based on keyword co-occurrence.

Cluster Theme	Top Keywords
1) AHP for life on land (Red)	Sustainable development, Urbanization, Ecosystem, China, Conservation, Forestry, Environmental monitoring, Environmental protection, Agriculture, Climate change
2) Natural hazard mapping and risk assessment (Green)	Remote sensing, Risk assessment, Flood control, Mapping, Vulnerability, Lithology, Landslides, Maps. Hazards, Satellite imagery
3) AHP for ecosystem conservation and restoration (Blue)	Groundwater resources, India, Water management, Spatial analysis Sensitivity analysis, Land cover, Aquifers, Water quality Geomorphology
4) AHP, GIS, and fuzzy logic for land use assessment and decision-making (Yellow)	AHP, GIS, Land use, Multi-criteria decision, Fuzzy logic, Iran, Information use, Information systems, Site selection, Turkey
5) MCDM approaches for restoring degraded land (Purple)	Watersheds, Soil conservation, Rain, Soil erosion, Rivers, Runoff, Catchments, River basin, Water conservation, Textures

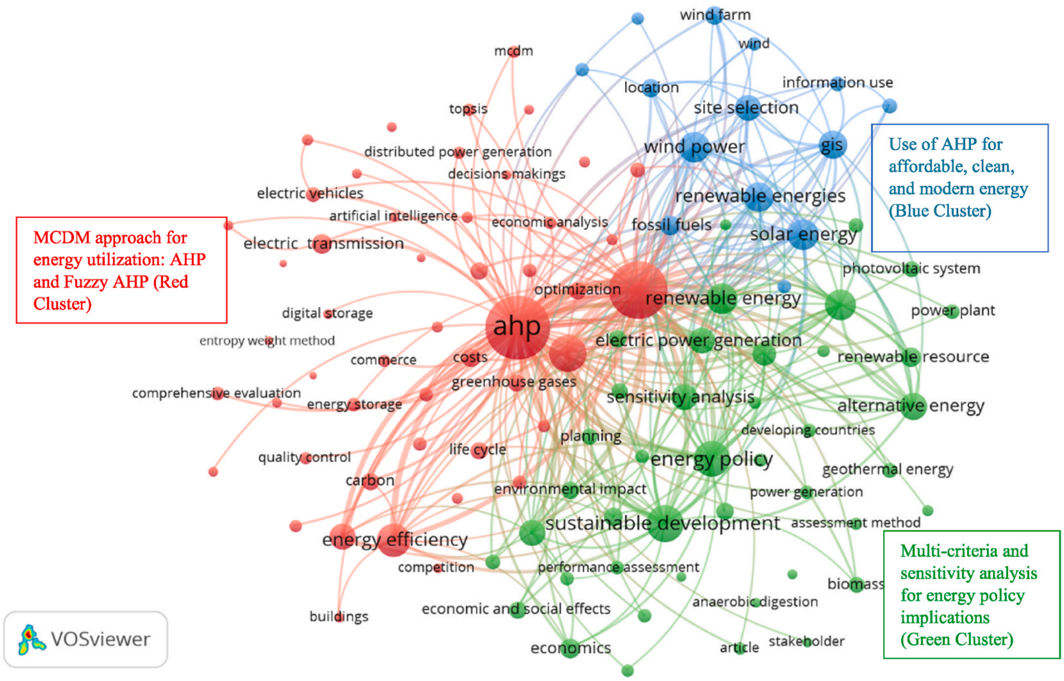

Fig. 12. Keyword co-occurrence network of SDG 7.

Table 3
SDG 15 clusters based on keyword co-occurrence.

Cluster Theme	Top Keywords
1) MCDM approach for energy utilization: AHP and Fuzzy AHP (Red)	AHP, Multi-criteria decision, Fuzzy AHP, Energy efficiency, Energy utilization, Electric transmission, Costs, Carbon, Optimization, Decision support systems
2) Multi-criteria and Sensitivity analysis for energy policy implications (Green)	Sustainable development, Energy policy, Renewable energy, Multi-criteria analysis, Alternative energy, Sensitivity analysis, Investments, Electric power generation, Energy resources, Renewable resource
3) Use of AHP for affordable, clean, and modern energy (Blue)	Solar energy, Wind power, Renewable energies, GIS, Site selection, Fossil fuels, Location, Wind farm, Information use, Information systems, Wind, Land use

components and parameters of a framework for energy education to enhance decision-making relating to SDG 7, which calls for clean and affordable energy availability.

3.5.3. SDG 12 (Responsible Consumption and Production)

Fig. 13 shows the keyword co-occurrence network of SDG 12 mapped publications.

This network offers insights into the most popular and important terms by employing circle size to denote importance. The separation between these circles reveals how closely related the terms are. Based on these keywords in Fig. 13, 3 cluster themes have emerged. Table 4 shows the three cluster themes and keywords in each cluster formed based on SDG mappings.

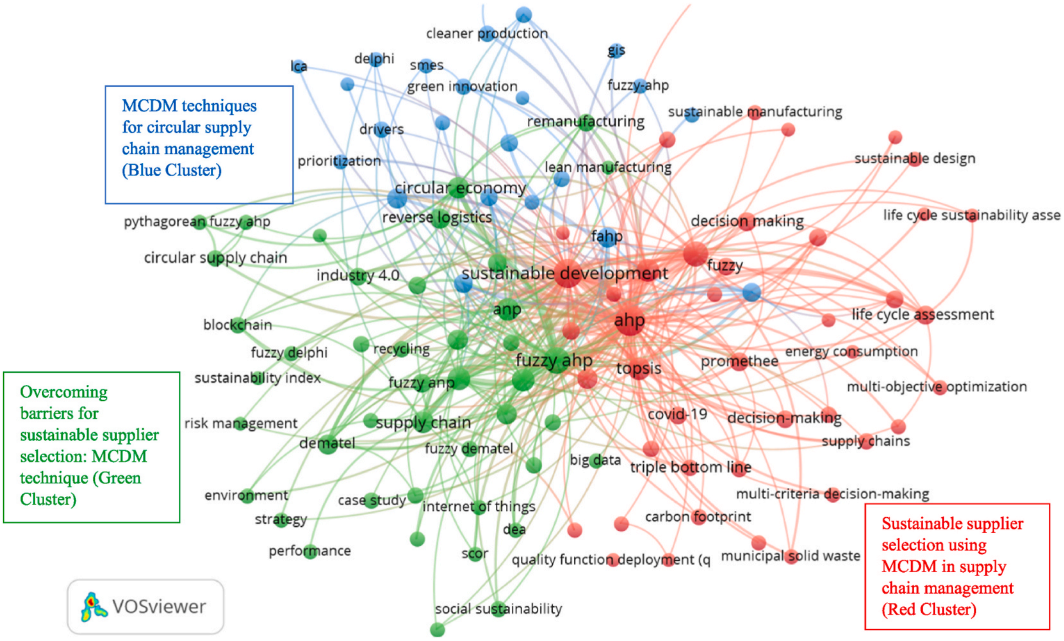

Fig. 13. Keyword co-occurrence network of SDG 12.

Table 4
SDG 12 clusters based on keyword co-occurrence.

Cluster Theme	Top Keywords
1) Sustainable supplier selection using MCDM in supply chain management (Red)	AHP, Sustainable development, Multi-criteria decision, TOPSIS, Supplier selection, Sustainable supply chain, Decision making, PROMETHEE, Life cycle assessment, Fuzzy theory
2) MCDM techniques for circular supply chain management (Blue)	Fuzzy AHP, Analytical Network Process (ANP), Supply chain management, MCDM, Circular economy, Supply chain, Fuzzy TOPSIS, DEMATEL, Green supply chain management, Reverse logistics
3) Overcoming barriers for sustainable supplier selection: MCDM technique (Green)	Fuzzy AHP (FAHP), Barriers, Sensitivity analysis, Sustainable supplier selection, Performance measurement, Fuzzy TOPSIS (FTOPSIS), Cleaner production, Performance evaluation, Analytical hierarchy process (AHP), Green innovation

1) ***Sustainable supplier selection using MCDM in supply chain management*** - The theme focuses on sustainable supplier selection in supply chain management using MCDM techniques such as fuzzy theory, AHP, and others [65–67]. The theme emphasizes the importance of life-cycle analysis and sustainable development in supply chain management, ensuring suppliers are economically viable and socially responsible. A rigorous and sustainability-focused assessment approach for supplier selection is required due to growing customer awareness and economic and stakeholder pressures [68].

2) ***MCDM techniques for circular supply chain management*** - This theme highlights the use of MCDM techniques, such as Fuzzy AHP, ANP, Fuzzy TOPSIS, and DEMATEL, for sustainable and circular supply chain management [69,70]. It emphasizes the importance of reverse logistics, green supply chain management, and the circular economy in promoting environmental Sustainability [71]. MCDM approaches can aid in identifying suppliers, products, and processes most compatible with the circular economy's principles.
3) ***Overcoming barriers for sustainable supplier selection: MCDM technique*** - The theme revolves around sustainable supplier selection using MCDM methods like Fuzzy AHP and Fuzzy TOPSIS [69,70]. It highlights the challenges in choosing sustainable suppliers and the need for sensitivity analysis for optimal supplier evaluation criteria [72]. The theme emphasizes the importance of performance evaluation, measurement, cleaner production, and green innovation in selecting sustainable suppliers. It underlines the need to overcome barriers to achieve sustainable supplier selection and the role of MCDM methods in identifying the most appropriate vendors for the supply chain [72].

3.5.4. SDG 13 (climate action)

Fig. 14 shows the keyword co-occurrence network of SDG 13 mapped publications.

This network offers insights into the most popular and important terms by employing circle size to denote importance. The separation between these circles reveals how closely related the terms are. Based on these keywords in Fig. 14, 4 cluster themes have emerged. Table 5 shows the four cluster themes and keywords in each cluster formed based on SDG mappings.

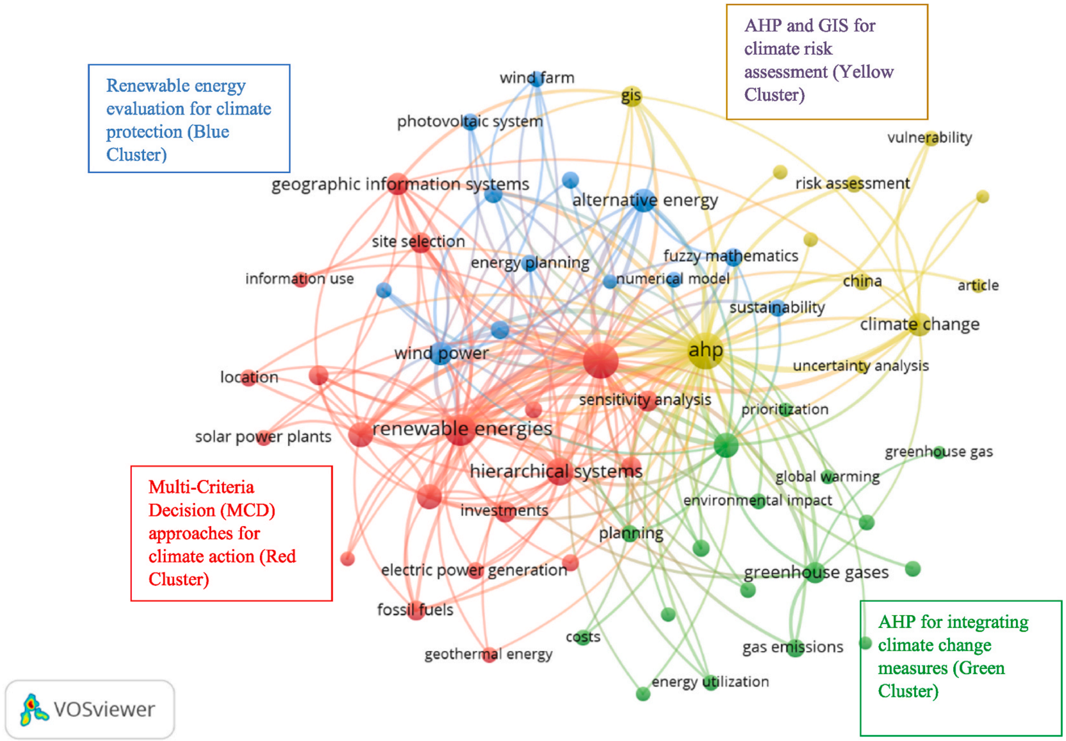

Fig. 14. Keyword co-occurrence network of SDG 13.

Table 5
SDG 13 clusters based on keyword co-occurrence.

Cluster Theme	Top Keywords
1) Multi-Criteria Decision (MCD) approaches for climate action (Red)	Multi-criteria decision, Renewable energies, Hierarchical systems, Energy policy, Solar energy, Geographic Information Systems, Site selection, Sensitivity analysis, Investments, Solar power generation
2) AHP for integrating climate change measures (Green)	Sustainable development, Greenhouse gases, Gas emissions, Planning, Energy efficiency, Energy utilization, Economic and social effects, Environmental impact, Emission control, Costs
3) Renewable energy evaluation for climate protection (Blue)	Alternative energy, Wind power, Fuzzy mathematics, Electric utilities, Electricity generation, Sustainability, Energy planning, Energy resource, Photovoltaic system, Wind farm
4) AHP and GIS for climate risk assessment (Yellow)	AHP, Climate change, GIS, Risk assessment, China, Vulnerability, India, Assessment method, Article, Uncertainty analysis

1) ***Multi-Criteria Decision (MCD) approaches for climate action*** - MCD techniques are valuable because they allow decision-makers to consider multiple options and make informed choices based on various criteria [73]. Ahmad et al. [18] developed a methodology for evaluating and ranking renewable options by examining the potential of different renewable resources. Their AHP model prioritizes resources, with solar as the top resource, followed by biomass. Uyan [74] used GIS and AHP to select the best locations for solar farms, considering factors such as topography, local meteorological conditions, accessibility to high transmission capacity lines, agricultural amenities, and environmental protection concerns.

2) ***AHP for integrating climate change measures*** - AHP can help integrate climate change measures into policy and planning by comparing the effectiveness and viability of various strategies and selecting the best ones. Luthra et al. [75] aimed to assess and identify the main challenges to deploying renewable and green energy technologies in the Indian context. Watson et al. [76] applied an MCDM framework with an AHP approach and expert stakeholders to improve site selection for renewable energy projects.
3) ***Renewable energy evaluation for climate protection*** - Evaluating renewable energy sources concerning their contributions to climate protection is essential. Höfer et al. [77] presented a comprehensive MCDM approach that includes techno-economic, socio-political, and environmental criteria. Büyüközkan et al. [78] emphasized the importance of renewable energy resources for sustainable development due to the depletion of reserves and the harmful effects of fossil fuels on the environment.
4) ***AHP and GIS for climate risk assessment*** - Integrating AHP and GIS for climate risk assessment is crucial for developing effective strategies to address climate change and mitigate its impacts. Combining these two approaches allows decision-makers to conduct more comprehensive, data-driven risk assessments that inform policies and planning initiatives. Sánchez-Lozano et al. [58]

combined GIS and MCDM methodologies to assess the best location for photovoltaic solar power plants. The integration of GIS and MCDM creates a powerful tool for analysis, allowing the development of an extensive database, including text and maps, that can be used with multi-criteria approaches to solve problems efficiently and promote using multiple criteria.

3.5.5. SDG 11 (sustainable cities and communities)

Fig. 15 shows the keyword co-occurrence network of SDG 11 mapped publications.

This network offers insights into the most popular and important terms by employing circle size to denote importance. The separation between these circles reveals how closely related the terms are. Based on these keywords in Fig. 15, 5 cluster themes have emerged. Table 6 shows the three cluster themes and keywords in each cluster formed based on SDG mappings.

1) ***AHP application for sustainable communities*** **-** AHP can help create sustainable communities by ranking and evaluating various options. Sustainable communities offer residents a high quality of life while minimizing adverse environmental impacts. Liang et al. [79] developed urban development and environmental pollution indicators using AHP, the entropy method, and the concept of minimum entropy. Syyadi et al. [80] provided an integrated framework for assessing sustainable transportation policy based on system dynamics and ANP, showing that trip-sharing-based policies are more effective for sustainability in transport networks.

2) ***Risk assessment for natural disasters*** - Risk assessment is essential for mitigating the effects of natural disasters. Schaefer and Thinh [81] highlighted the potential of remote sensing and GIS technologies for urban planners to monitor agricultural loss and improve decision-making for future land management. Orencio and Fuji [82] developed a local-level index for a disaster-resilient coastal community, emphasizing national-level risk management and vulnerability-reduction system elements.
3) ***AHP for green and resilient buildings*** **-** AHP can help prioritize sustainability criteria for constructing green and resilient buildings, making the decision-making process more objective, transparent, and thorough. Khoshnava et al. [83] used a hybrid MCDM methodology to manage multiple conflicting green building material criteria, employing the Decision-Making Trial and Evaluation Laboratory (DEMATEL) and a fuzzy analytic network process (FANP).
4) ***Fuzzy AHP for socio-economic-environmental protection*** **-** Fuzzy AHP can help evaluate various concerns, leading to more rational decisions that protect social, economic, and environmental well-being. Lombardi et al. [84] analyzed the relationships between the triple helix model's three pillars—universities, businesses, and governments. Awasthi et al. [85] provided a hybrid technique for analyzing city logistics projects based on an affinity diagram, AHP, and fuzzy TOPSIS.
5) ***Application of GIS for waste management*** **-** GIS systems can assist waste management by creating maps and analyzing the spatial distribution of waste generation. Soltani et al. [86] reviewed the literature on the application of MCDA for solving municipal solid waste management problems, finding that AHP was the most commonly used method when considering multiple stakeholders and that experts and governments were the most frequently involved parties in these studies.

3.6. Social network analysis

The current study used network analysis to discover research hotspots and changes and gain insights into new research fields.

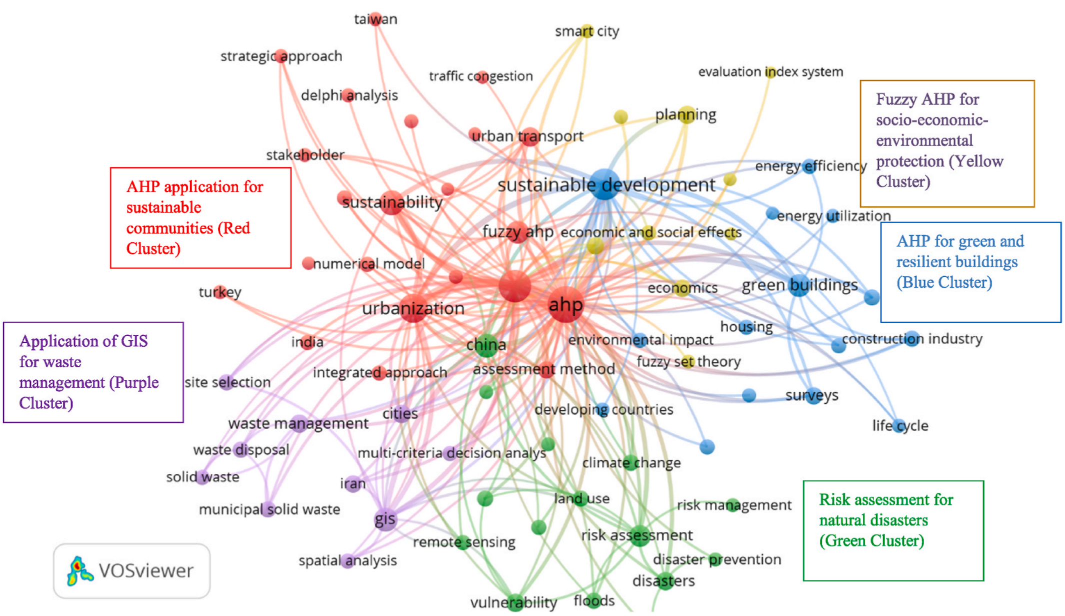

Fig. 15. Keyword co-occurrence network of SDG 11.

Table 6
SDG 11 clusters based on keyword co-occurrence.

Cluster Theme	Top Keywords
1) AHP application for sustainable communities (Red)	AHP, Multi-criteria decision, Urbanization, Sustainability, Fuzzy AHP, Urban transport, Assessment method, Integrated approach, Numerical model, Public transport
2) Risk assessment for natural disasters (Green)	China, Risk assessment, Disasters, Vulnerability, Land use, Floods, Disaster management, Climate change, Population statistics, Remote sensing
3) AHP for green and resilient buildings (Blue)	Sustainable development, Green buildings, Surveys, Architectural design, Construction industry, Energy efficiency, Housing, Construction, Environmental impact, Fuzzy logic
4) Fuzzy AHP for socio-economic-environmental protection (Yellow)	Planning, Environmental protection, Economics Economic and social effects, Fuzzy set theory, Smart city, Quality control, Comprehensive evaluation, Fuzzy comprehensive evaluation method, Evaluation index system
5) Application of GIS for waste management (Purple)	GIS, Cities, Waste management, Iran, Municipal solid waste, Waste disposal, Site selection, Spatial analysis, Multi-criteria decision analysis, Solid waste

Utilizing Social Network Analysis (SNA), this study identified a close relatedness between SDGs where AHP research has been conducted. As a result, the actors can be viewed as nodes in a cooperation network or as links connecting various subnetworks [87]. Consequently, this study has investigated centrality, betweenness, and MICMAC analysis as components of social network analysis. Fig. 16 demonstrates the SDG Social Network based on the eigenvector measure. Eigenvector centrality is used to identify the importance of a node within a network by considering direct and indirect connections. By analyzing the SDG network using eigenvector analysis, we can determine the most influential or interconnected SDGs, which are considered the "leaders" of the network. The top five SDGs based on eigenvector centrality are SDG 7 (0.082), SDG 9 (0.077), SDG 16 (0.067), SDG 6 (0.064), and SDG 5 (0.059). Identifying these leaders can help policymakers and stakeholders prioritize their efforts and resources to achieve these Goals, as they are crucial for the overall success of the SDG network.

Fig. 17 displays the SDG Social Network based on the betweenness measure, which indicates the degree of co-citation between nodes. Betweenness centrality counts how often an SDG is located on the shortest path between two other nodes. High betweenness Goals are considered influential and significantly affect the network. The top five influential SDGs based on the betweenness measure are SDG 7 (0.0064), SDG 9 (0.0036), SDG 6 (0.0036), SDG 16 (0.0022), and SDG 13 (0.0022). Recognizing influential SDGs using the betweenness measure can help policymakers and stakeholders prioritize their efforts and resources toward achieving these goals since they are vital for the success of the SDG network.

Fig. 18 illustrates the MICMAC analysis results, a cross-impact analysis technique used to classify components based on their driving and dependent forces. The graph generated by the MICMAC analysis divides components into four zones: driving, autonomous, dependent, and linkage factors.

This study applied the MICMAC analysis to identify five SDGs primary drivers and dependencies, including SDG 13, SDG 2, SDG 12,

Fig. 16. SDG Social Network based on eigenvector measure.

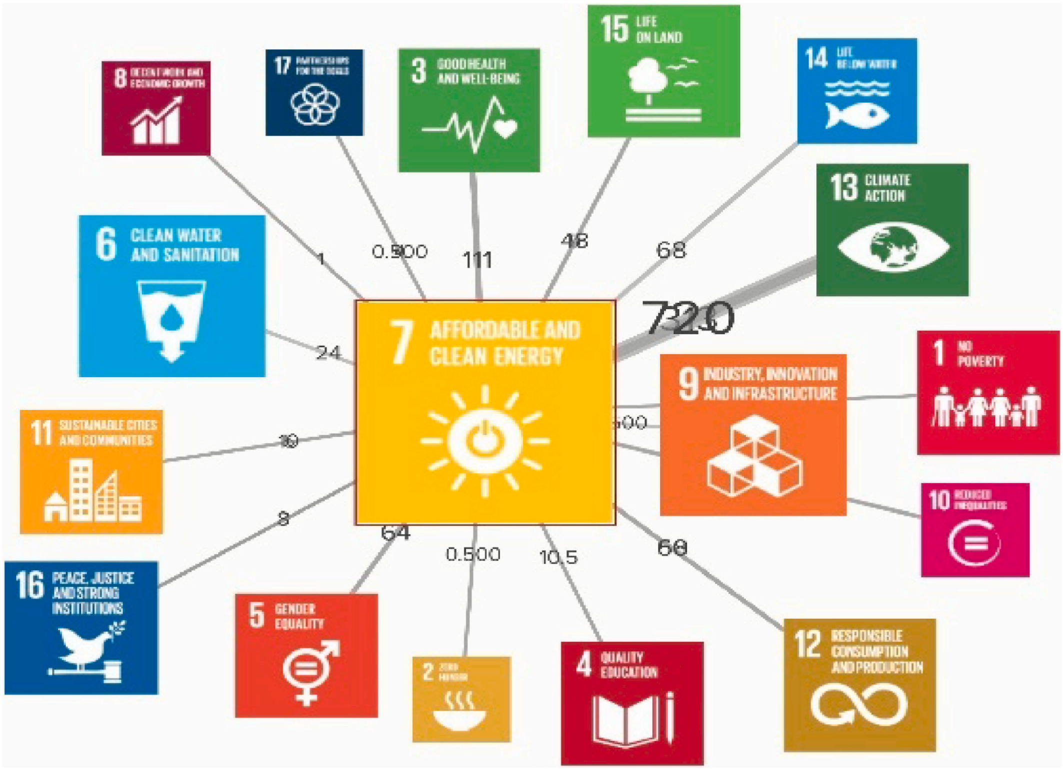

Fig. 17. SDG Social Network based on betweenness measure.

SDG 4, and SDG 16. According to the analysis, SDG 2 emerged as a crucial goal for achieving sustainable development, with the highest effect score of 0.94 among the 17 goals examined. SDG 13, with a score of 1, is identified as a vital goal whose progress is essential for sustainable development. Additionally, SDGs 12 (0.801), 4 (0.689), and 16 (0.684) were recognized as important SDGs necessary for attaining sustainable development.

By identifying these key SDGs through the MICMAC analysis, policymakers and stakeholders can better understand the driving forces and dependencies within the network of SDGs, allowing them to focus their efforts and resources on the most influential and interconnected goals.

4. Future research directions

Although this study has shed light on the landscape of AHP research and its relationship to SDGs, several directions for further investigation might lead to a more comprehensive understanding of the subject. These directions for research seek to fill in gaps, deal with constraints, and investigate new prospects. Promising areas for additional research include the ones listed below.

4.1. Integration of other MCDM techniques

Although the use of AHP in addressing SDGs was the main emphasis of this study, other MCDM techniques are also available that might be investigated to improve decision-making processes. Future studies could look into combining AHP with supplementary approaches like "ELECTRE (Elimination and Choice Translating Reality)," "Multi-Attribute Utility Theory (MAUT)," and "Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)." Comparative analyses and assessments of various strategies within the framework of sustainable development could shed light on their advantages, disadvantages, and potential synergies.

4.2. Application of AHP in specific sustainable development domains

Although this study offered a comprehensive overview of AHP research across several SDGs, there is still room for more in-depth studies in particular fields. The use of AHP in areas including renewable energy, water resource management, urban planning, and climate change adaptation may be explored in further research. Such studies would allow for a greater comprehension of the particular difficulties and opportunities within these sectors and offer decision-makers-focused recommendations.

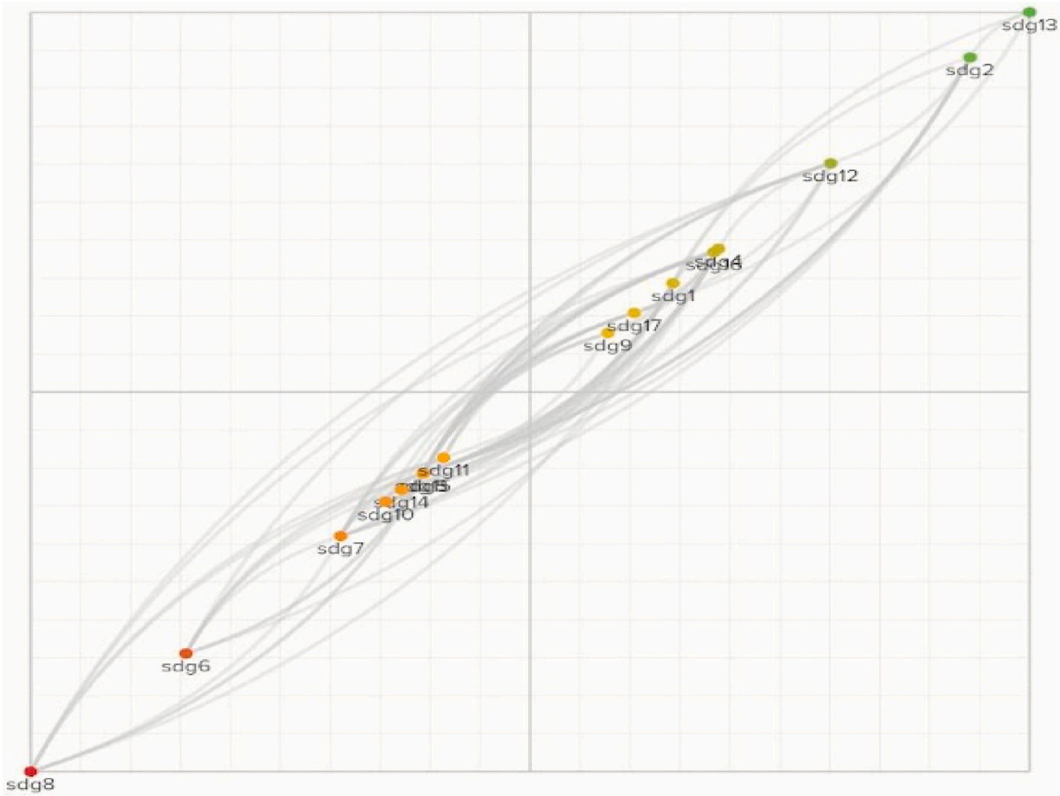

Fig. 18. MICMAC cross-impact analysis.

4.3. Development of a hybrid decision-making approach

Future studies could examine the creation of hybrid approaches that integrate AHP with other methodologies, such as machine learning, data mining, and optimization techniques, to further improve decision-making processes in sustainable development. These hybrid strategies might use the advantages of many methodologies to offer more reliable and precise decision assistance tools. Furthermore, incorporating big data and real-time data may improve the efficiency and promptness of decision-making in complex and dynamic sustainability environments.

4.4. Assessment of AHP implementation and impact

Future research may move its emphasis from analysing published research articles to examining how effectively AHP is used and how it affects actual sustainability projects. This study largely focused on analyzing research articles that had already been published. Case and longitudinal studies could provide insight into the difficulties, triumphs, and lessons discovered when using AHP in various settings. Additionally, investigating the function of stakeholders, institutional frameworks, and policy implications in AHP-based decision-making processes would offer insightful information on the elements affecting its efficacy and uptake.

4.5. Ethical consideration in AHP-based decision-making

Future studies could focus on the ethical issues connected to AHP-based decision-making processes because sustainable development encompasses social, economic, and environmental components. Ethical frameworks and norms may be created to ensure that AHP-based decision-making processes follow ethical concepts, including equality, justice, inclusivity, and transparency. AHP implementation could lead to biases, unforeseen consequences, and trade-offs that need to be looked into to create more morally sound decision-support systems.

These directions for research suggest possible areas for more investigation and development in the area of AHP research and its relationship to Sustainable Development Goals. Researchers can help create stronger and more useful decision-making frameworks that support sustainable development projects by addressing these gaps and seizing newly available opportunities.

5. Conclusion

The Analytic Hierarchy Process (AHP) is a popular approach for dealing with complex issues requiring a number of criteria [88,89]. The SDGs of the UN offer a global structure for tackling the most urgent social, economic, and environmental issues. To add to this crucial and timely field of research, we have decided to explore the SDG angle in AHP research in this paper. Our study extensively analyzed the publications and citations related to Analytical Hierarchy Process (AHP), focusing on how well these publications map to Sustainable Development Goals. The approach of examining 29,000+ total publications, specifically focusing on 10,000+ aligned with SDGs, is innovative in bibliometrics analysis. Furthermore, using social network analysis and centrality measures to examine SDG-mapped AHP publications added another layer of novelty.

Our study used total publications and citations to determine AHP trends and SDG evolution, revealing that AHP publications increased in frequency until 2021. The top five evolved SDGs were 15, 7, 12, 13, and 11. The University of Tehran was the top contributor, with the highest research productivity and influence. China had the highest research productivity and influence among countries. The Journal of Cleaner Production was the top-cited journal in AHP research contributing to sustainability.

The study used keyword co-occurrence network analysis to identify clusters of critical SDGs and their connections, revealing three distinct SDG clusters. The top five environmentally related SDGs had multiple clusters associated with various sustainability topics, such as AHP for life on land, MCDM approach for energy utilization: AHP and Fuzzy AHP, Sustainable supplier selection using MCDM in supply chain management, MCD approaches for climate action, AHP application for sustainable communities, to name a few. This analysis offers valuable insights into the intricate interconnections between various SDGs, assisting policymakers in developing strategies to achieve sustainable development goals.

We identified SDG leaders using social network analysis, including eigenvector, betweenness, and MICMAC analysis. Eigenvector centrality identified the top five SDGs as 7, 9, 16, 6, and 5. High betweenness SDGs were considered influential, with SDG 7 being the most influential. A MICMAC study determined the primary drivers and dependencies for five SDGs – SDG 13, SDG 2, SDG 12, SDG 4, and SDG 16.

Hence, this paper adds to the body of literature by reviewing AHP research in the context of the SDGs using bibliometric and social network analysis. We improve our understanding of how AHP might contribute to sustainable development and guide decision-making processes for reaching the SDGs by mapping the existing AHP literature and identifying its links with the SDGs. The application of our results enables stakeholders to use AHP to address difficult problems and advance sustainable development across various fields. Ultimately, this study establishes the foundation for additional research and AHP methodology applications in achieving sustainable development goals.

It is vital to recognize research limitations, such as potentially missing relevant publications during keyword searches and excluding grey literature. Additionally, the study's timeframe only considered publications from 2012 onwards. Despite these limitations, the study's encouraging results can inform future research, with a comprehensive literature review or meta-analysis of the AHP approach building upon this work and providing deeper insights into its application.

Author contribution statement

Aswathy Sreenivasan: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
M. Suresh: Conceived and designed the experiments.
Prema Nedungadi: Performed the experiments; Contributed reagents, materials, analysis tools or data.
Raghu Raman R: Conceived and designed the experiments; Analyzed and interpreted the data.

Data availability statement

Data included in article/supp. Material/referenced in article.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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