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GIS-based AHP and MCDA Modeling for Cropland Suitability Analysis: A Bibliometric Analysis

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Keywords

Analytical Hierarchy Process
Bibliometric Analysis
Cropland
Geographic Information System
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Abstract

The ' Land Suitability Analysis ' is a useful management method for ensuring that agricultural lands are utilized sustainably and planned based on their potential. Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) for cropland suitability analysis have seen substantial contributions from researchers worldwide. This combination assesses and maps the suitability of land for different crops by utilizing the multi-criteria decision analysis (MCDA) strengths of AHP and the spatial analytic capabilities of GIS. This Bibliometric analysis involves examining publications to identify patterns and trends, such as the most prolific authors & Countries, influential journals, and highly cited papers. It helps in understanding the development and current state of a research field. Using Biblioshiny software, the researchers obtained 183 publications of 687 authors and 319 different institutions using the bibliographic information from the Scopus database. The bibliometric analysis uses the following subcategories: Country, Authors, Publication Sources, Annual Scientific Production, and keywords. By examining the outcomes of bibliometric analysis, methodology, and applications, it was discovered that AHP and MCDA are the most often utilized techniques in this respect. Also, the findings indicated a rising number of publications and a growing interest in the subject, especially in recent years. Over the previous 23 years, the overall trend of publications in this field grew gradually at an annual growth rate of 21.81%. Asian nations, especially China, India, and Iran, have had the biggest influence on the nation's scientific output in the discipline. During this period, India and Iran had the most research papers published. In addition, "GIS," "Land Suitability," and "AHP" are the top three most often used terms. Future trends in this subject are predicted by the current keywords: "GIS," "Land Suitability," "AHP," and "Remote Sensing." Moreover, this exhaustive investigation provides a basis for comprehending the present status and future direction of GIS-based cropland suitability research. These discoveries offer valuable insights for future modeling and research endeavors on the subject and aid in identifying research gaps in the existing literature.

Cite

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1. INTRODUCTION

Of all the natural resources available, agricultural resources are considered to be the most important renewable and dynamic resource (Sathiyamurthi et al., 2022). In this manner, the term "suitability" refers to a function that is dependent on land elements and crop requirements; it is similar to a metric that describes the characteristics of the land unit to compare the needs of a particular land use (FAO, 1976). Analyzing a land area's suitability for a certain type of land use is a methodical process known as Land Suitability Analysis (LSA). Assessment of land suitability by FAO guidelines has been implemented in many parts of the world, especially in developing nations (FAO, 1976). A piece of land's appropriateness for agricultural production is determined by how well it can withstand crop production over time (Singha & Swain, 2016). To determine if a piece of land is suitable for a particular agricultural crop, many factors must be taken into consideration.

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These include biophysical components involving relief (elevation), terrain slope, field drainage, soil qualities, nutrient content, atmospheric conditions, vegetative aspects, etc. When making significant judgements, this also takes into account social, ecological, and cultural factors (Abushnaf et al., 2013). To combine geographically referenced data, GIS is typically recognized as a decision support system (Özkan et al., 2019). Expert views are used in the multi-criteria decision-making (MCDM) process, which involves assessing a set of alternatives about several criteria (Liao et al., 2023). Many complex decision-making issues have been resolved with its help (Chiao, 2021; Torkayesh et al., 2021; Baydas et al., 2022). Some of the MCDM techniques used in site selection difficulties are the Elimination and Choice Translating Reality (ELECTRE), Weighted Linear Combination (WLC), AHP, and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). (Wigati et al., 2019). Geographical problems involving geographic data, such as site selection problems, are sometimes known as spatial or geographical decision problems. The advancement of spatial query and analysis systems in GIS has been greatly aided by the rapid advances in computer technologies during the early 2000s. Several studies have revealed that the use of ArcGIS software for geographic decision support systems has increased in this era, which is recognized for its long-lasting effects (Miller & Goodchild, 2014). A few advantages of MCDA-GIS integration include its ability to assist stakeholders and policymakers in the crucial process of defining evaluation criteria (Palmisano et al., 2016). Alfred Weber first put out the idea of site selection theory in 1909, concentrating on the need to locate the depot closest to every customer. The selection of location is a constantly fascinating novel issue. Finding the best location with the required circumstances while taking into account a variety of factors is known as site selection. A thorough assessment of the site selection procedure is offered by the application of GIS-based MCDA techniques, which combine various datasets and criteria using geospatial technology to provide a suitability map that shows regions appropriate for cropland.

Over the past few decades, GIS has become widely used in the field of agricultural science. Additionally, research on agricultural productivity has been done with fuzzy logic, fuzzy TOPSIS, and AHP-MCDA (Houshyar et al., 2014; Maleki et al., 2017; Kahsay et al., 2018; Amin et al., 2020). Continuous factors can be modeled for a suitability assessment within a GIS study thanks to the fuzzy set theory (Purnamasari et al., 2019). Land adaptability must be evaluated to facilitate productive planning and long-term, sustainable land usage. Tashayo et al. (2020) used AHP-Fuzzy and GIS to examine whether land in the saline, calcareous, and sodic soils of the Marvdasht Plain, which is in southern Iran, was suitable for growing wheat. Habibie et al. (2021) assessed the land suitability study with the use of several criterion considerations and GIS in order to ensure the sustainability of maize production in Tuban Regency, Indonesia. Further, according to fifteen socio-environmental, physical, and climatic characteristics, Musakwa (2018) investigated the appropriateness of cropland in South Africa. In Sri Lanka, Jayasinghe and Withanage (2021) have utilized GIS-MCDA techniques to determine potato land suitability. Their analysis included a diverse array of criteria such as soil pH, salinity, elevation, slope, aspect, market proximity, and land use. Also, the assessment of land is crucial in this regard since it offers details on the possibilities and limitations of the land for a specific type of land use about crop productivity (Habibie et al., 2021). Many models have been developed to estimate crop output through remote sensing applications, thanks to the quick growth of spectral reflectance and remote sensing technologies (Sakamoto et al., 2013; Lobell et al., 2015; Zabihi et al., 2015; Azzari et al., 2017). A significant amount of literature has been produced over the years by the many researchers who have created models and methods for creating maps of land suitability around the globe. Numerous fields have had a literature review on the application of GIS-MCDA integration for site selection problems that have been conducted, including cropland suitability (Purnamasari et al., 2019; Kılıc et al., 2022; Sathiyamurthi et al., 2022), landslide susceptibility (Huang et al., 2022; Özkan et al., 2019; Chinthaka et al., 2023), and solar photovoltaic power plant site selection (Al Garni & Awasthi, 2018; Rediske et al., 2018), for solid waste site selection (Wijesinghe & Fernando, 2023). For scholars, the literature—which consists of multiple papers has offered a useful summary of land suitability.

The appropriate results are important for academics to identify the main topics, consider potential avenues for future investigation, and seek collaboration with other organizations or nations in a certain field of study (Huang et al., 2022). It is necessary to do more thorough literature studies that examine the contributions of research experts, the field's evolution, topics, and upcoming academic possibilities related to cropland suitability. A popular strategy for examining published literature is bibliometric analysis, which is a contemporary approach in computer engineering, database management, and statistics (Qin et al., 2022).

Bibliometrics is a statistical analysis used in various scientific fields to assess books, journal articles, and other written communication formats on a specific topic. This paper employs bibliometrics analysis to demonstrate the current state of research and the direction of development for the usage of AHP-MCDA models in cropland suitability applications. Bibliometrics allows researchers to analyze the growth and development of research over time. By examining publication trends, one can identify peak periods of interest and the evolution of the field. By analyzing keywords and their co-occurrence, bibliometrics helps in identifying major themes, sub-fields, and emerging topics within the domain of GIS-based AHP and MCDA modeling for cropland suitability. The bibliometrics analysis to quantify and understand the landscape of research involving AHP-MCDA models in cropland suitability. It looks at the volume and trends of scientific production, identifies key contributors, most prolific countries, influential journals, and highly cited papers, and provides insights into where future research might be headed. Identifies which countries or regions are conducting the most research on this topic, indicating where cropland suitability is a significant concern. This helps researchers and stakeholders understand the current state of the field and make informed decisions about future research directions. Not only that, A thorough summary of the body of research is given by Bibliometrics, summarizing key findings, methodologies, and theoretical advancements in the field. The method facilitates the creation of visual representations (such as co-citation networks, thematic maps, and collaboration graphs), making complex data more accessible and understandable. As far as the researcher is aware, no research has ever undertaken a bibliometric review on cropland suitability anywhere in the world. Insights from bibliometric analysis can inform policymakers and planners about effective strategies for land use and agricultural development. Therefore, to fill the research gap in this area, this work investigates the gaps in the literature and conducts a thorough bibliometric study on GIS-based cropland suitability for the years 2010 to 2023. Additionally, this manuscript attempts to address the following questions:

RQ1: How are the Annual Scientific Productions related to the GIS-based cropland Suitability?

RQ2: Who are the most impactful (Cited) authors on the subject of GIS-based cropland Suitability?

RQ3: Which are the most influential journals (Sources) in this area of research?

RQ4: Which countries have contributed to international collaboration and what is the total number of publications related to this area of research?

RQ5: What are the relevant author keywords and trending topics for years for future research direction related to GIS-based cropland Suitability?

The problems above are essential to understanding the general context of GIS-based AHP-MCDA techniques used in the agriculture sectors. This work aims to elucidate the current state of research and development trends regarding the use of AHP-MCDA models in the agricultural environment by applying content analysis and bibliometrics.

2. MATERIALS AND METHODS

This work employed a bibliometric analysis to assess the quality of prior research and present an extensive overview of the current status of scientific output, offering a plethora of data on the respective topic. The database was visually inspected and filtered before outliers were discovered. After that, it was examined using the R environment's "Bibliometrics" package and the Biblioshiny app (R CoreTeam, 2016; Aria & Cuccurullo, 2017). Bibliometric analysis can highlight under-researched areas and gaps in the existing literature, guiding future research directions and strategies. It enables comparative analysis of different research entities, helping researchers and institutions benchmark their performance. By employing the bibliometrics method, researchers can systematically and comprehensively analyze the vast literature available in this field. This provides a structured approach to understanding the field’s dynamics, identifying influential research, and guiding future studies. A standard bibliometric analysis consists of the following five steps: research design, data collection, analysis, visualization, and interpretation (Zupic & Čater, 2014). With the aid of bibliometric technology, information may be retrieved from the repository by classifying and analyzing vast volumes of historical data that were the result of a study done during a specific period (Ejaz et al., 2022). Doing a comprehensive

bibliometric analysis of the literature in GIS-based cropland suitability helps to achieve the goals of this study. Figure 1 illustrates this research methodology for gathering and analyzing data.

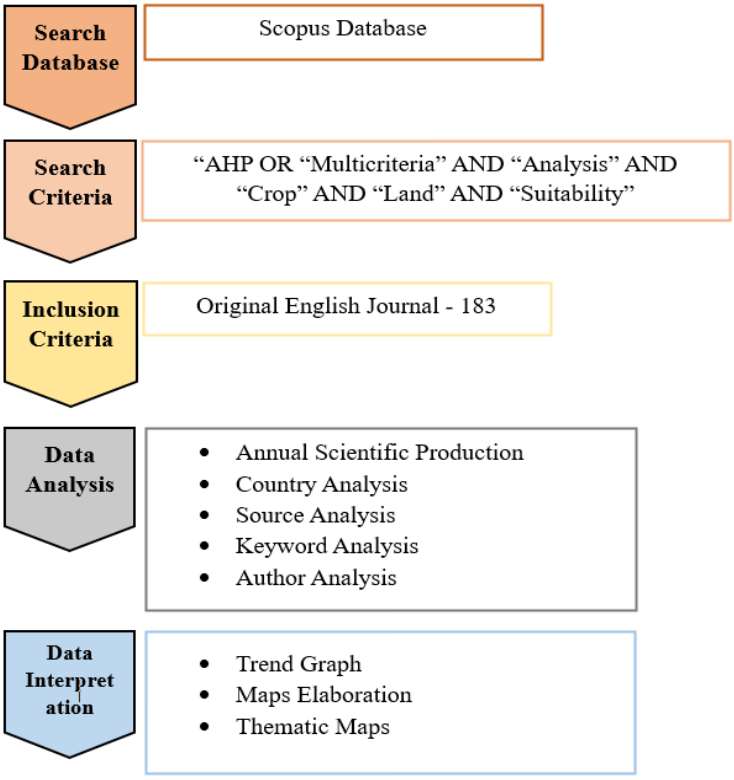

Figure 1. *Methodology Process*

2.1. Materials

2.1.1 Data Collection

The current study searches for pertinent documents using the Scopus database. Launched in 2004, the Scopus database is one of Elsevier's well-known databases. Compared to other academic databases, Scopus has a greater number of articles (Veloutsou & Mafe, 2020). Also, for a more in-depth analysis, this database's comprehension and ability to support numerous inclusion and exclusion criteria are essential (Rautela et al., 2024). Choosing and utilizing precise keywords that can yield precise database findings is one of the most crucial phases of bibliometric research. The search parameters included "Article title, Abstracts, and Keywords." Identified keywords were combined using the Boolean operators "AND/OR" to refine the search results. In the Scopus database, the search terms included "AHP OR "Multicriteria" AND "Analysis" AND "Crop" AND "Land" AND "Suitability." In the next step, the document type was 'Article', the language was selected as 'English Language' and limited to published documents from 2010 to 2023. Ensured to include relevant fields such as author(s), title, source (journal/conference), abstract, keywords, DOI, publication year, citations, and affiliations. To be used in the bibliometric study that followed, the final records were exported from the Scopus database in Comma-Separated Value (CSV) format. As a data cleaning part, then removed duplicates, irrelevant articles, and non-English papers if necessary. After, Extracted bibliographic information such as authors, publication year, journal, keywords, abstracts, and citations. Depending on the scope of the study, the researcher might choose to focus only on English-language papers to maintain consistency and comprehensibility. also, manually inspected titles and abstracts to confirm relevance, especially for borderline cases where keyword matching may not be conclusive. By thoroughly cleaning the data, researcher determine that the subsequent bibliometric analysis accurately reflects the research landscape of GIS-based AHP and MCDA modeling for cropland suitability analysis. Also, the data format is required to meet the input requirements of the Bibliometrix package in R. Ultimately, 183 publications were chosen for further investigation in this study.

2.1.2 Data Analysis and Interpretation

The researchers examined and visualized the present and future orientations of Cropland Suitability using GIS, using the Bibliometric program from R 4.4.0 Software and the Biblioshiny web interface. With bibliographic data taken from the Scopus database, Biblioshiny analyses a wide range of categories in analytics and graphs, from individual contributions to the social network (Moral-Muñoz et al., 2020). Using the R programming language and the Shiny package, Massimo Aria developed the Biblioshiny software (Aria & Cuccurullo, 2017). Also, a readily interpretable bibliometric map is displayed by the bibliometric visualization tool VOSViewer (Rautela et al., 2024). This study examined how the volume of research has evolved. Identify periods of increased interest and potential reasons for these trends. Identify dominant themes and emerging topics in the field of cropland suitability analysis using GIS, AHP, and MCDA. Also, highlight key papers and authors that have significantly contributed to the field. Understand the impact of foundational studies. Further, Quantify publications over time, journal distributions, country-wise contributions, and author productivity. İn this context, the researcher Understands how AHP and MCDA are applied to weight criteria and makes decisions in land suitability analysis. Additionally, it might provide a visual representation of how the field of study has grown and changed. Moreover, create maps, charts, and graphs to visualize bibliometric patterns and GIS-based suitability results. These include trend graphs, the production of the top authors over the graph, corresponding author country figures, country maps, appropriate sources, and thematic maps. Finally, provide insights for policymakers on land-use planning and sustainable agricultural practices based on suitability analysis results.

3. RESULTS

3.1 Scientific Productivity in the Field of GIS-based Cropland Suitability

To understand a study field's development state and trend, it can be useful to analyze the number of publications over time. Using the Scopus Database, 183 research publications on GIS-based cropland suitability published between 2010 and 2023 were examined for this study. There has been a notable advancement in this subject recently, and numerous studies are being presented in this regard. In many countries, one can witness an attempt to concentrate on various investigations by utilizing the technical knowledge associated with this. As a result, from 2010 to 2023, the publication of research articles of the chosen scope directly increased, as seen in Figure 2. With an R-square of 83%, the equation shown in Figure 2 can forecast the documents published annually. Research paper publication has increased between 2018 and 2023, and this trend is distinct in that it will increase by 21.31% by that year. There were less than ten published research publications between 2010 and 2017. Researcher publications from 2018 to 2023 comprised a substantial amount of 145 publications, and 38 papers were published overall in those 07 years. It's evident from looking at the research articles' citations that there hasn't been any improvement.

Figure 3 displays the average number of citations per article and year for the article. Concerning the evolution of the number of citations annually, it should be noted that the decrease in citations recorded for the 2019–2023 period can be explained by the fact that, as would be expected, the temporal frame within which publications published in the years close to the conclusion of the analysis year can be cited is smaller. After receiving 8.38 Mean Total Citations annually for three years starting in 2010, there were a few minor increases noted. The paper "GIS-based land suitability assessment for tobacco production using AHP and fuzzy set in Shandong province of China," written by Zhang, Su, Wu, and Liang and published in 2015, has the most citations which received 197 (Zhang et al., 2015). Furthermore, the highest point in data for 2018 and 2019 can be seen in Figure 3, which shows the evolution of the average annual article citations. The paper "Development of a Model Using Matter Element, AHP, and GIS Techniques to Assess the Suitability of Land for Agriculture," written by Seyedmohammadi et al. and published in 2019, had 114 citations during this period (Seyedmohammadi et al., 2019). 93 papers were published between 2021 and 2023, with an average annual total citation of 7.09. Of those, 30 papers were published in 2018 and 2019, accounting for a total of 12.63 citations.

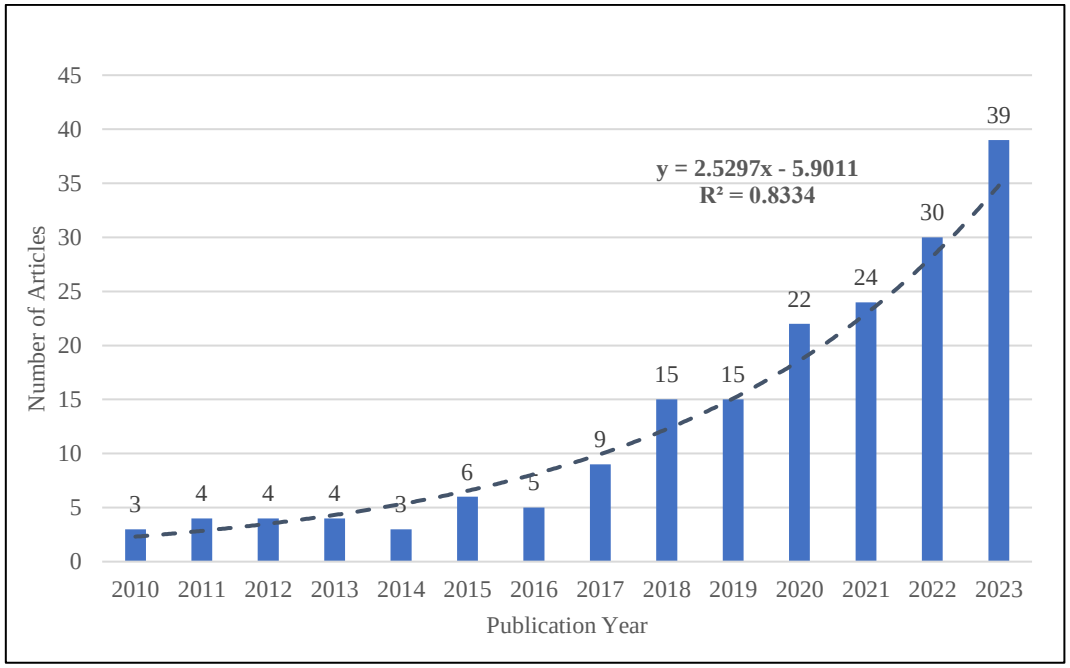

Figure 2. *Annual Scientific Production*

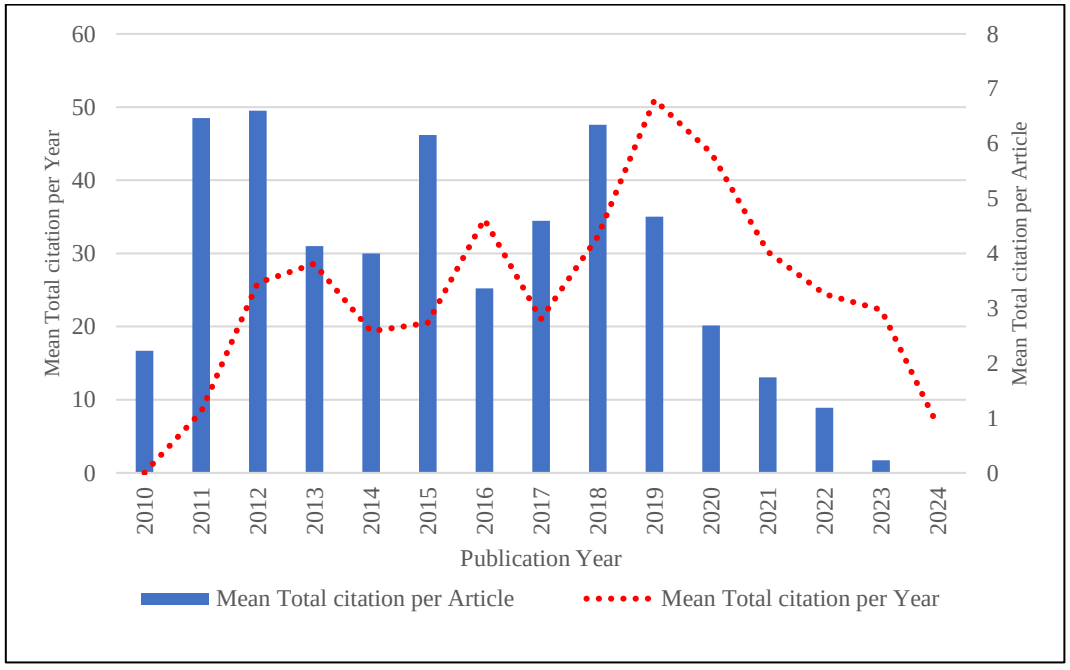

Figure 3. *Distribution of Mean Citations of Documents Yearly*

According to Figure 4, a three-field plot (Sankey diagram) of the Author's nation (AU_CO), Authors (AU), and Keyword (DE) of publication of the cited references was constructed to indicate the percentage of study topics for each nation and the recentness of the papers they cited. The names of the contributing researchers are displayed in the middle column, nations are represented in the left column, and the most popular keywords used by these writers are displayed in the right column. A precise and well-illustrated depiction of well-known academics, their nations, and the knowledge management-related fields of interest are highlighted with keywords. It demonstrates that the most often used terms, which are mostly associated with the most referenced references, are "Land Suitability," "GIS," and "AHP." The Analytical Hierarchy method, GIS, land suitability, and remote sensing are the main areas of interest for researchers utilizing GIS to investigate land suitability in Peru. The majority of studies on consent have been published in Croatia, Peru, Japan, China, Iran, and India publish a limited amount of research on GIS and land suitability.

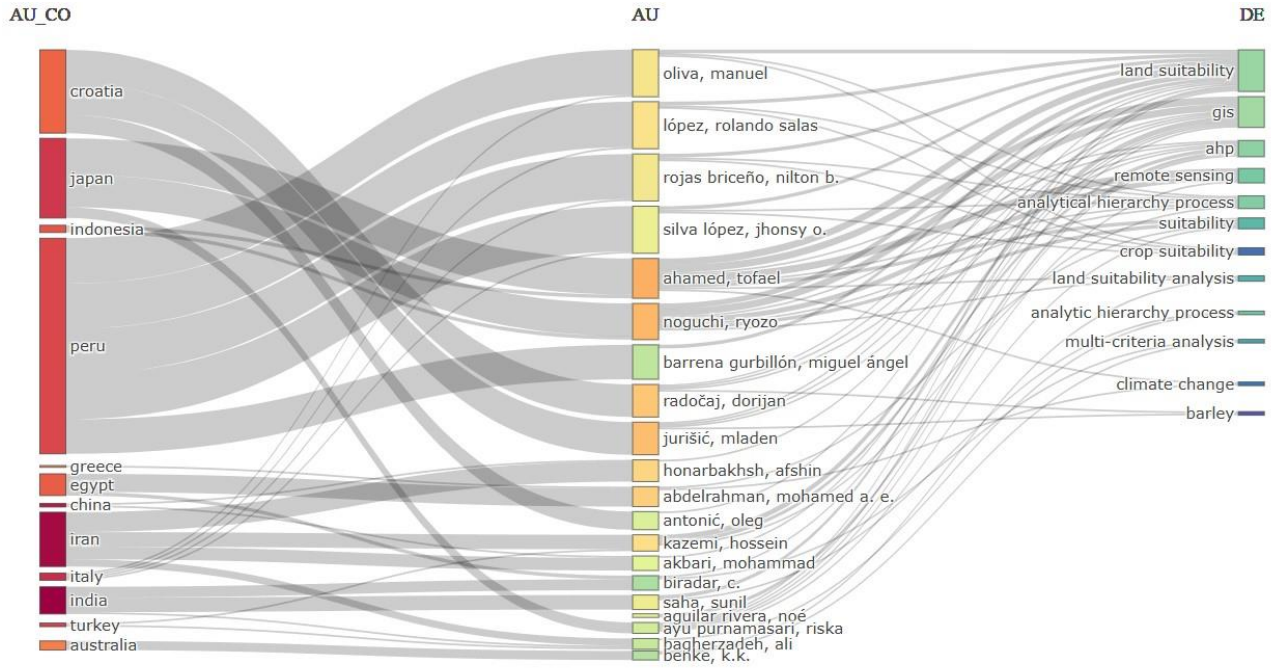

Figure 4. *Three-field Plot (Sankey diagram) of Author's Country, Authors, and Keyword*

3.2 Author Analysis

In the study, there were 687 authors in entirety. Table 1 identifies the highest-cited authors, with more than 100 citations, as Ahamed, T., Noguchi, R., Honarbakhsh, A., and Kazemi, H. Since Ahamed and Noguchi have 'h' index values of 5 and 'g' index values of 7 and 6, respectively, they are the most prominent authors. Furthermore, Jurisic, M. (63 citations) and Radocaj, D. (63 citations) have both made significant contributions to the literature in terms of the total number of citations. Due to the excellent quality of the numerous publications, they have written and published on the subject, Ahamed T. and Noguchi R. are well-regarded in the field of GIS-based cropland suitability analysis. The publication began in 2018, as shown in Figure 5, where the size of the circle indicates the number of documents and the colour shade indicates the number of citations. The years 2019 to 2022 noticed the highest number of published papers as well as the highest frequency of average citations per item. 42 citations were found in an article by Ahmed that was presented in the Computers and Electronics in Agriculture journal and was titled "Land suitability assessments for yield prediction of cassava using geospatial fuzzy expert systems and remote sensing" (Purnamasari et al., 2019). Using LSA to evaluate suitable sites, the research goal was to create a yield prediction model. In addition, ecological categories were used in a multi-criteria decision-making process together with a fuzzy expert system to identify priority indicators. Noguchi was the second most published author with a 'h' index of 5 and a 'g' index of 6, respectively. Titled "Land Suitability Analysis for Maize Production in Indonesia Using Satellite Remote Sensing and GIS-based Multicriteria Decision Support System," the article from 2021 that has received the most citations belongs to him. The author Honarbakhsh, A., produced the third-highest citation count with 'a' h index and a 'g' index of 3 respectively. He wrote articles about AHP–GIS for cropland Suitability Modelling as recently as 2020, and his initial publication dates back to 2019.

In the present investigation, an attempt has been made to calculate the relative concentration of GIS-based cropland suitability contributors by using Lotka's law. According to Figure 6, which depicts those 622 authors who published one article and one author who published more than six, individual productivity was determined to accord with Lotka's Law (1926) about the distribution frequency. It was determined that the correlation coefficient was r = 0.4147. According to Lotka's law, the productivity of authors in terms of publications is negatively correlated with their number of authors.

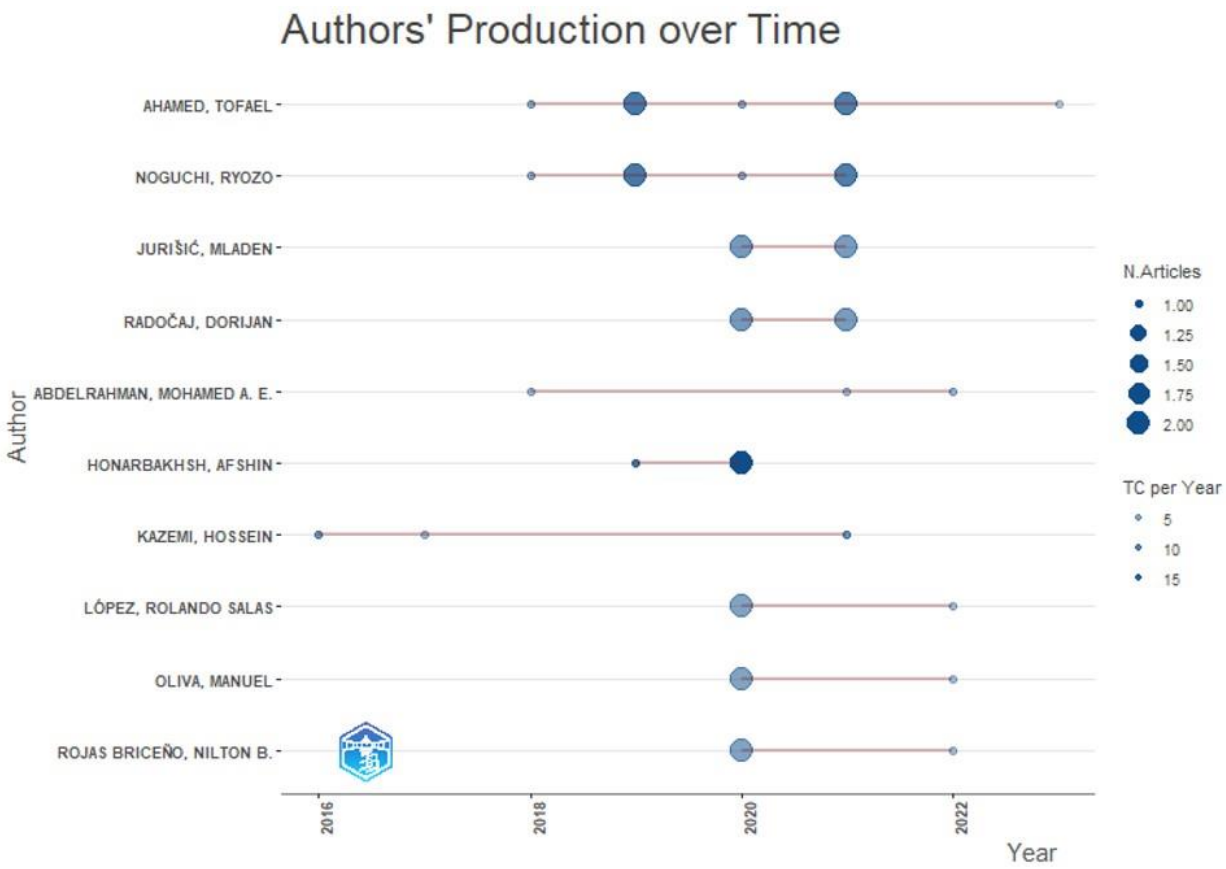

Figure 5. *The Production of the top Authors Over Time*

Table 1. *Most Impactful Authors*

Element	h_index	g_index	m_index	TC	NP	PY_start
Ahamed Tofael	5	7	0.71	166	7	2018
Noguchi Ryozo	5	6	0.71	165	6	2018
Jurišić Mladen	4	4	0.8	63	4	2020
Radočaj Dorijan	4	4	0.8	63	4	2020
Abdelrahman Mohamed A. E.	3	3	0.42	37	3	2018
Honarbakhsh Afshin	3	3	0.5	156	3	2019
Kazemi Hossein	3	3	0.33	114	3	2016
López Rolando Salas	3	3	0.6	34	3	2020
Oliva Manuel	3	3	0.6	34	3	2020
Rojas Briceño Nilton B.	3	3	0.6	34	3	2020

Source: Based on Biblioshiny Software

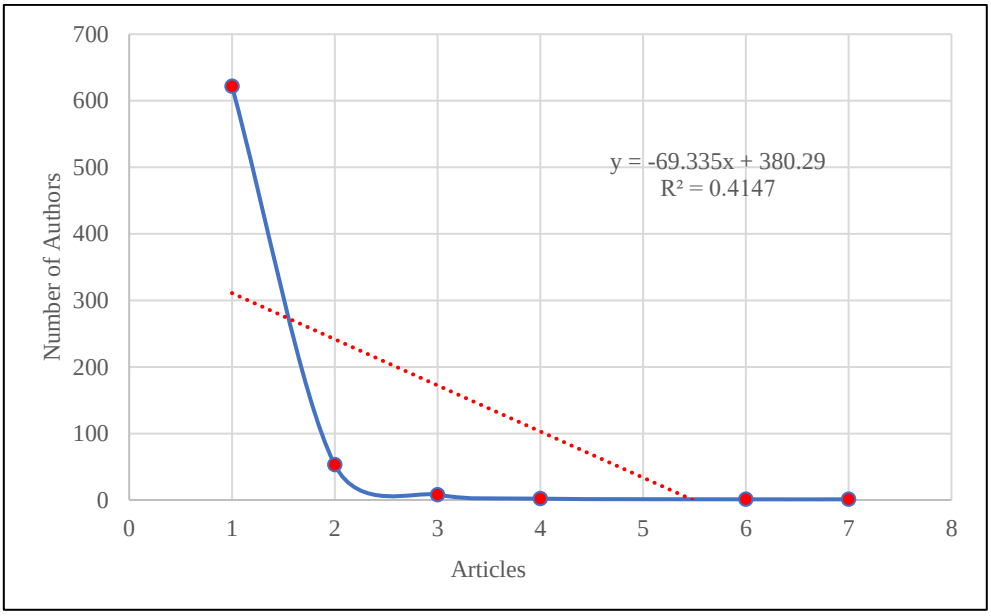

Figure 6. *Lotka's Law in GIS-based Cropland Suitability Research*

3.3 Source Analysis

Figure 7 displays the results of the top 10 most pertinent sites that have published research publications on GIS-based cropland Suitability. The outcome was produced based on Scopus data that was retrieved between 2010 and 2023. Sustainability is identified as the most important and pertinent source. The greatest number of publications and the most significant source of references for research on themes related to GIS-based cropland suitability analysis were published by this journal. For example, the studies included under these categories have been published in the Sustainability. "Crop-Suitability Analysis Using the Analytic Hierarchy Process and Geospatial Techniques for Cereal Production in North India" and "Land Suitability Planning for Sustainable Mango Production in Vulnerable Region Using Geospatial Multi-Criteria Decision Model". The top 10 most relevant journals, Sustainability Switzerland, Computer and Electronics in Agriculture, Ecological Indicators, and Modelling Earth System and Environment, are shown in Figure 8 based on citation, impact, and number of articles based on the H-index. Also, in the upcoming years, it is anticipated that the issue will continue to receive a significant number of citations in pertinent publications.

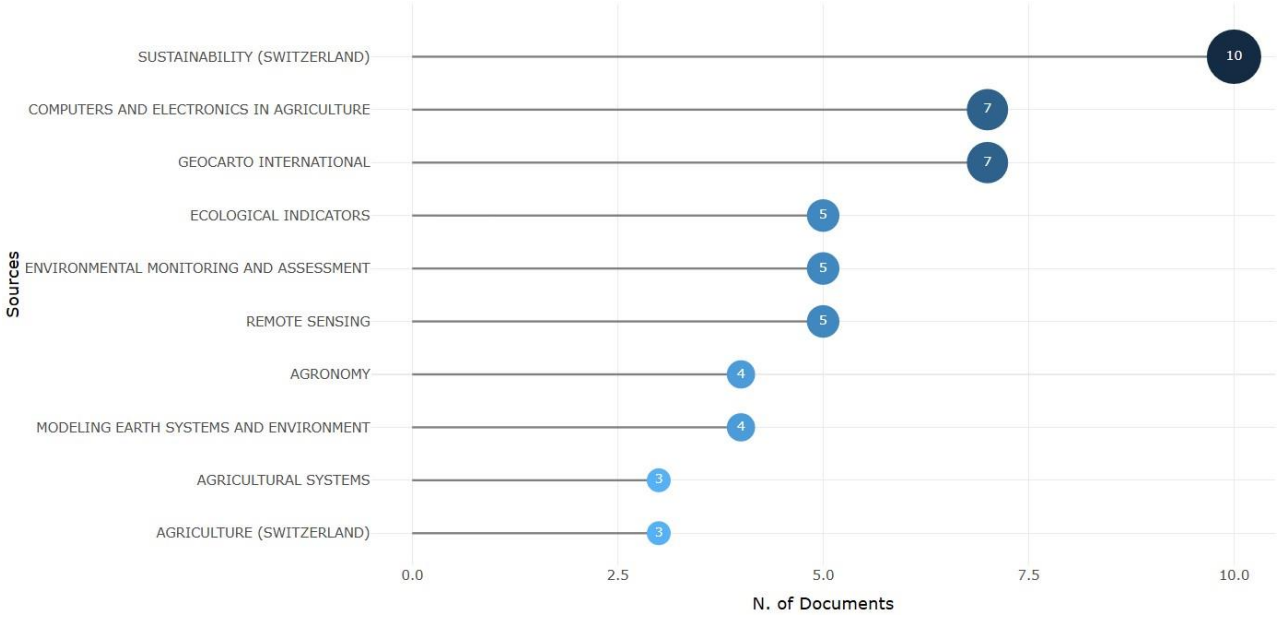

Figure 7. *Distribution of Publications based on Different Sources*

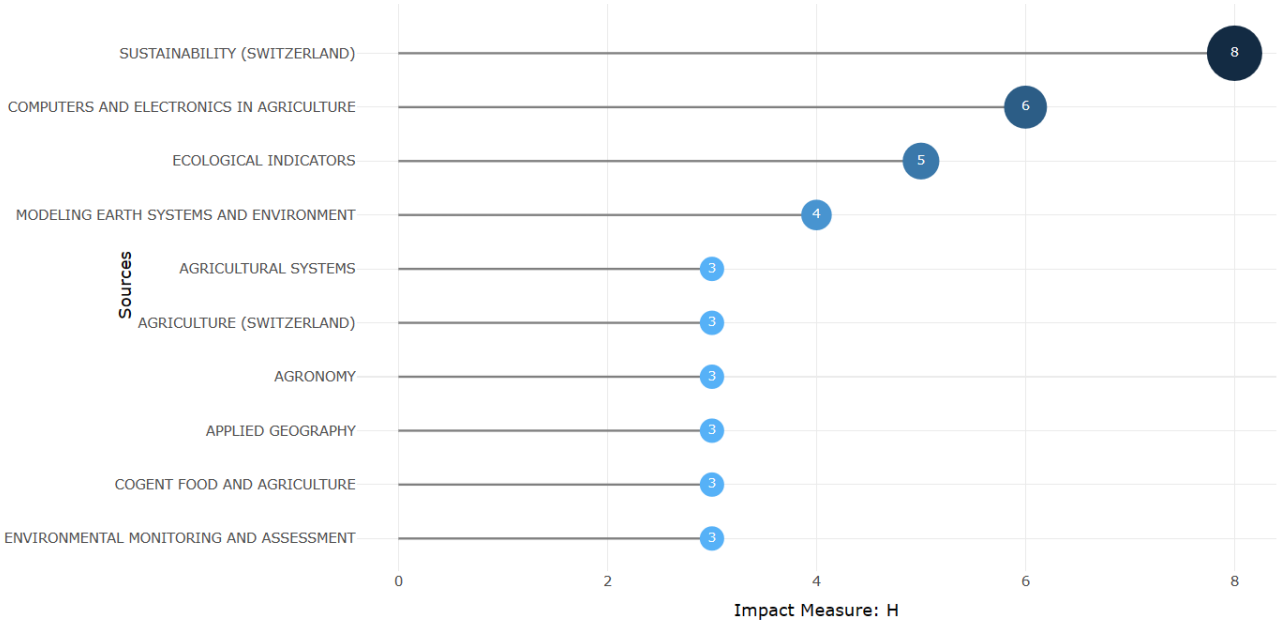

Figure 8. *Sources Local Impact by h-index*

According to Table 2, the term "The Most Local Cited Sources (from Reference Lists)" refers to a bibliometric analysis method that finds the sources that are most commonly mentioned in a certain field of study or research area. The process normally entails looking through the references of scientific publications to identify the sources that authors in a certain field, in this case, cropland suitability cite most frequently. According to the Zhang et al. (2015) study "GIS-based land suitability assessment for tobacco production using AHP and fuzzy set in Shandong province of China," which is presented in the table below, this approach offers an overview of the most important and pertinent document in the GIS-based cropland suitability area of research which, according to the Journal of Computers and Electronics in Agriculture, represented 40 local citations and 197 global citations, respectively. On the other hand, the other two most highly cited documents, both locally and globally, are Kazemi et al. (2016) from Ecological Indicators, which has 19, 64 local citations and global citations respectively, and Ostovari et al. (2019), also from Ecological Indicators, who has 68 worldwide citations. In particular, for the first three study publications, LC/GC ratios of 20.30%, 29.69%, and 25% can be found, respectively. In this field of study, this can be used to identify the principal theories, methodologies, approaches, and conclusions. Additionally, it can help observe how a field evolves and spot new patterns and potential study areas.

A pattern that calculates the exponentially declining rewards of looking up references in science publications is known as the Bradford Law. Samuel C. Bradford originally described this pattern in 1934 (Bradford, 1934; Black, 2004; Yatsko, 2012). The results of Bradford's law source clustering are shown in Figure 9 & Table 3, which attempts to visually depict the distribution of documents in a field among multiple journals so that we may determine which journals are most responsible for the area's relevant literature. Only 13 journals were determined to be in the core zone out of the 116 total sources using Bradford's formula. Additionally, the middle and minor zones contained, respectively, 43 and 60 of the journals. This indicates that a significant number of publications on the subject of GIS-based cropland suitability and AHP, MCDA are probably published in these 13 journals, whereas the content in the other sources may be less relevant or less frequently published on that particular issue. The most significant and fundamental sources are several journals, including "Sustainability (Switzerland)", "Computers and Electronics in Agriculture", "Geocarto International", and "Ecological Indicators". As a result of this, among the primary sources, Sustainability is the most frequently cited and highly relevant publication. This indicates that Bradford's law can be applied to the present research that has been filed and is relevant in this instance. This demonstrates the high calibre of the database and the articles that it has found and added about GIS-based cropland suitability research conducted country-wise. Nevertheless, citation counts alone do not indicate a journal's value and impact; other metrics, such as the quantity of publications, are also positively connected with it.

Table 2. *Most Local Cited Document*

Document	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations	Normalized Global Citations
Zhang et al., 2015, Comput Electron Agric	2015	40	197	20.30	5.58	4.27
Kazemi et al., 2016, Ecol Indic	2016	19	64	29.69	4.52	2.54
Ostovari et al., 2019, Ecol Indic	2019	17	68	25.00	7.73	1.94
Seyedmohammadi et al., 2019, Geoderma	2019	10	114	8.77	4.55	3.26
Kihoro et al., 2013, Springerplus	2013	10	92	10.87	4.00	2.97
Tashayo et al., 2020a, Environ Manage	2020	8	40	20.00	6.07	1.99
Tashayo et al., 2020b, J Saudi Soc Agric Sci	2020	8	48	16.67	6.07	2.38
Sarkar et al., 2014, Geo-Spatial Inf Sci	2014	8	37	21.62	1.85	1.23
Worqlul et al., 2017, Appl Geogr	2017	7	98	7.14	4.20	2.85
Jamil et al., 2018, Agric Res	2018	6	31	19.35	2.81	0.65
Vasu et al., 2018, Land Use Policy	2018	5	68	7.35	2.34	1.43
Seyedmohammadi et al., 2018, Geoderma	2022	5	33	15.15	21.43	3.71

Source: Based on Biblioshiny Software

3.4 Country Analysis

Table 3 highlights the top 10 nations with the largest number of citations, even though authors from 38 different countries or regions contributed to the study. Italy and Portugal are the two European nations in the top 10, while the top five nations are overall—Iran, India, China, Korea, and Japan. The specialization is that the top five countries are all located in Asia, and the contribution of conducting research in those nations is noteworthy. The majority of research publications on GIS-based cropland Suitability are published in developing regions, such as Asia, as Table 4 demonstrates. These results imply that these areas are leading the field. With a significant disparity between India and China (with 418 and 364 citations, respectively), Iran was expected to hold the top spot with a sizable 708 citations with 32.2 Average Article Citations. Studying GIS-based analysis may have a greater theoretical and practical impact on countries that are developing. Further, the number of papers published in a given country on a certain topic may serve as a proxy for the country's stature and influence in the field of GIS-based analysis research.

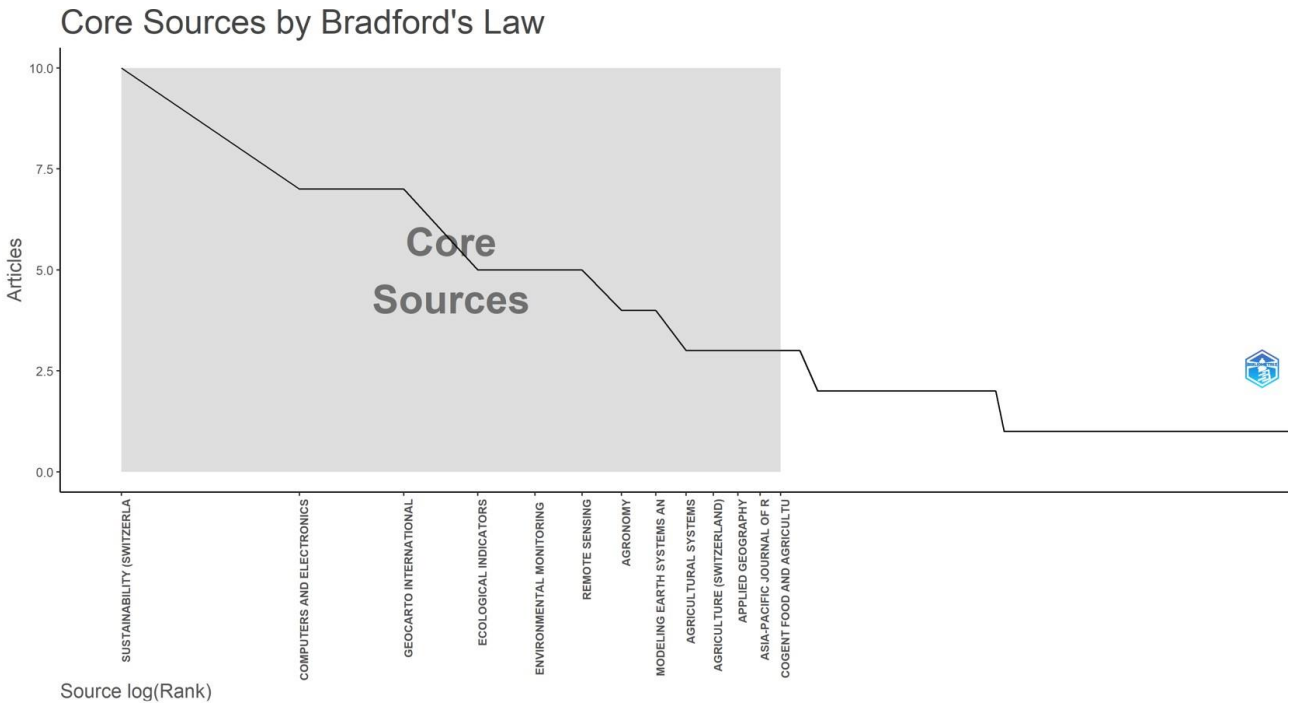

Figure 9. *Core Sources by the Bradford's Law*

Table 3. *Core Sources based on Bradford's Law*

Source	**Freq**	**cumFreq**	**Zone**
Sustainability (Switzerland)	10	10	Zone 1
Computers And Electronics In Agriculture	7	17	Zone 1
Geocarto International	7	24	Zone 1
Ecological Indicators	5	29	Zone 1
Environmental Monitoring And Assessment	5	34	Zone 1
Remote Sensing	5	39	Zone 1
Agronomy	4	43	Zone 1
Modeling Earth Systems And Environment	4	47	Zone 1

Figure 10 displays the articles' geographic distribution. The frequency observed to be higher than the number of articles analyzed is explained by the figure, which is based on the co-occurrence of the nation's according to the affiliations of the authors. Upon examining the top ten most productive nations, it is evident that most of them are found in the continents of North and South America, Asia, Africa, and Europe. India is an incredibly productive partner for other nations. With 19.78% of the 48 countries, India has a considerably higher document number (frequency) than any other country. However, the field of cropland suitability utilizing GIS in India has many documents, but the average article citation per item is only 12.7, suggesting that the article level still has to be further enhanced. Seven different countries have collaborated on at least one study. At a rate of 148, 73, 42, and 38 times a year, respectively, China, India, Iran, and the United States are all involved in frequent collaborations. Portugal is the nation with the most average citations per item, coming in at number 58.3, while its document count only makes it to the 7th. It demonstrates that the article level is high despite the low document count. Additionally, the graphic shows that there are more local authors when the shades of blue go from lighter to darker. In contrast, grey denotes the absence of local authors. In theory,

emerging nations and agricultural countries stand to gain more from the study of GIS-based agricultural land suitability. Among them, some agriculturally oriented regions were unable to support greater academic research due to a lack of funding and a relatively low level of science and technology. Moreover, it is challenging to hold a significant number of positions in the world due to the lack of technology, money, and talent pools in many emerging nations.

Table 4. *Most Cited Countries*

Country	Total Citation	Average Article Citations
Iran	708	32.2
India	418	12.7
China	364	40.4
Korea	210	10.5
Japan	203	18.5
USA	194	27.7
Portugal	175	58.3
Turkey	153	15.3
Italy	144	20.6
Ethiopia	114	12.7
Source: Based on Biblioshiny Software		

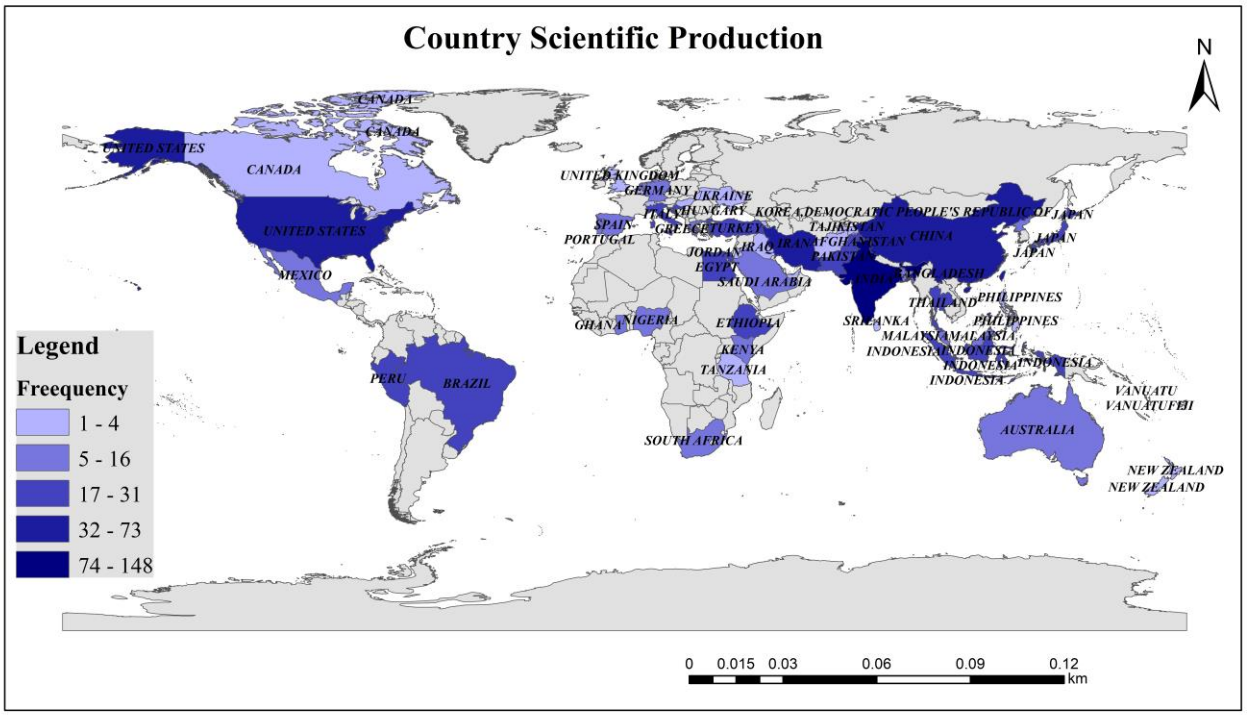

Figure 10. *Country Scientific Production*

Figure 11 displays the number of publications in which each article is categorized by the Corresponding author's association with a particular nation. This research is intended to ascertain the proportion of publications in which at least one author is linked to a nation other than the one of the corresponding author. Only domestic authors are featured in more publications than authors from other countries. More research on GIS-based cropland suitability has been published in India than in any other country, albeit the majority of these studies were carried out on their own. The findings showed that there were generally a considerable number of papers written by Indian authors. The GIS-based cropland Suitability collaboration data of sample countries reveal that 21.53 percent of Indian publications are prepared independently. While there is more than a 35% multiple-country collaboration ratio, nations like Egypt, Brazil, and Pakistan are involved in international collaboration. In particular, specifically, no articles spanning multiple countries are visible in Indonesia and Croatia. However, nine distinct nations were found to have a higher level of international collaboration (MCP ratio = 1.0) but have just one multiple-country article: Armenia, Bangladesh, Ghana, Netherlands, New Zealand, South Africa, Tanzania, Ukraine, and the United Arab Emirates.

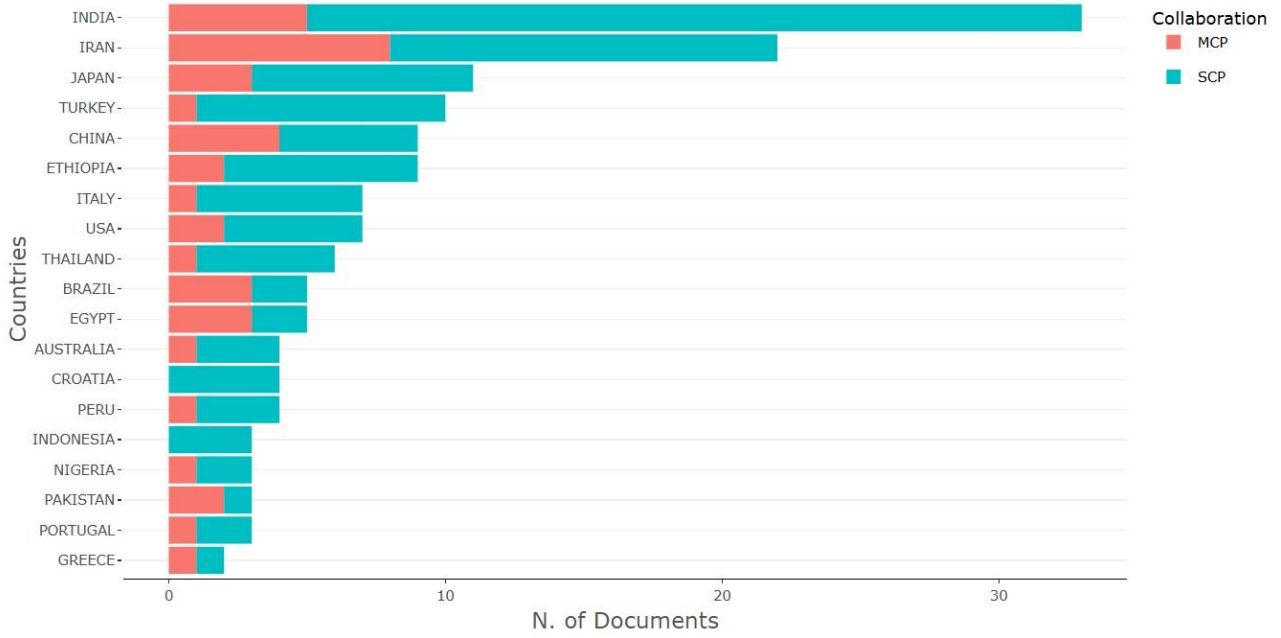

Figure 11. *Corresponding Author's Country*

3.5 Keyword Analysis

Using keywords, the article's main points are clarified and high-level summarized. The software program biblioshiny does statistical analysis and data mining on the research articles' high-frequency keywords. The most commonly occurring keywords in the GIS-based land suitability analysis are chosen and shown in Table 5 and Figure 12 as those with word frequencies greater than or equal to 7. The research papers' high-frequency keywords are subjected to statistical analysis and data mining using the software package Biblioshiny. The concept and writing approach to the paper in the GIS-based cropland suitability is succinct and reflected in the analysis of keywords like cluster analysis and multiple correspondence analysis. The keywords "GIS," "Land suitability," and "AHP" are most commonly used in the context of GIS-based cropland suitability; they account for 24.5%, 22.5%, and 16.8% of explorations, respectively. The reader can also comprehend the potential boundaries of GIS-based research through the keyword analysis.

The theme map relative to the appropriateness of cropland by GIS is shown in Figure 13. The themes that are currently popular in this field of study are presented visually. Based on the topics' density and centrality, thematic maps are separated into four quadrants, each of which symbolizes a distinct topic typology. Density is a measurement of the theme's evolution, while centrality indicates the theme's significance throughout the full investigation of this image. A high level of centralization and density is implied by the prevalence of motifs in the upper-right quadrant. Author keyword clusters and their relationships are the source of topics for the thematic analysis. These themes have characteristics that define them. A node is considered more central and

important if it has a higher number of relations with other nodes in the theme network and has an essential location within the network. Cohesion inside a node, which symbolizes the density of a field of study, similarly defines the field's capacity to grow and endure. The top-right portion of the map displays the themes that have recently gained significance. The driving themes are shown in the upper right quadrant (Q1), underlying themes are shown in the lower right quadrant (Q4), much-specialized themes are shown in the upper left quadrant (Q2), and emerging themes are shown in the lower left quadrant (Q3) (Pai et al., 2022). Author Keywords have a deeper and more varied ability to convey the substance of an article.

Table 5. *Frequency Analysis of Authors' Keywords*

Words	Occurrences	% Occurrences
GIS	51	24.5
Land Suitability	47	22.5
AHP	35	16.8
Analytical Hierarchy Process	18	8.6
Remote Sensing	13	6.25
Analytic Hierarchy Process	10	4.8
Analytical Hierarchy Process (AHP)	10	4.8
Suitability	9	4.3
Land Suitability Analysis	8	3.8
Multi-Criteria Analysis	7	3.3

Source: Based on Biblioshiny Software

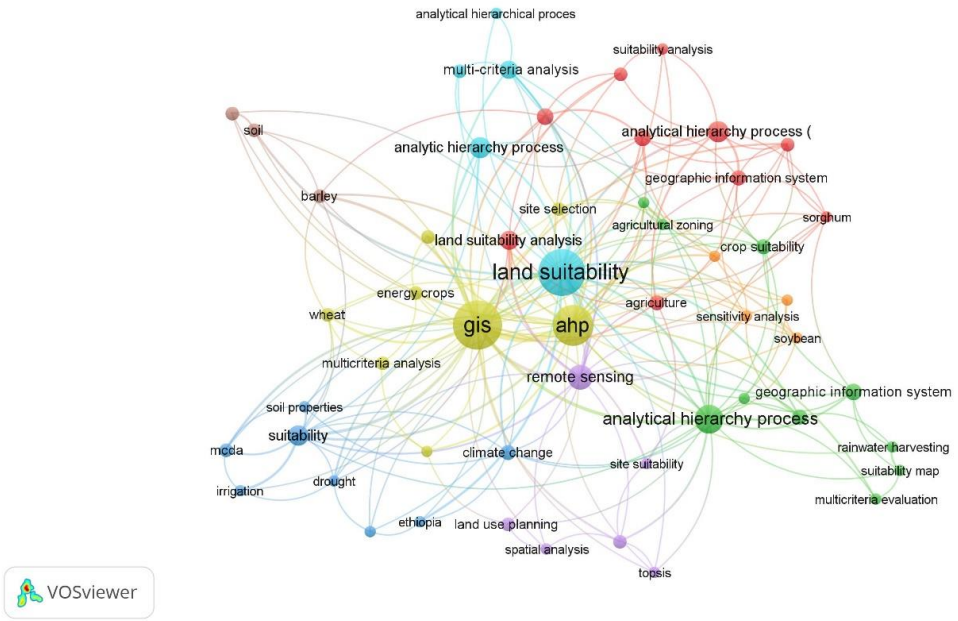

Figure 12. *Keywords Trend of the Most Utilized Words*

The motor themes are displayed in Q1. They are distinguished by high density as well as centrality. Two of the "motor themes" that have received the greatest attention in the literature are "Land Suitability" and "GIS". In this review, sustainable development is the main focus. Performance, progress, technical advancement, and sustainability are just a few of the numerous ideas that are related to this theme. Since our initial subject categories were "suitability," "modeling," "assessment," and "evaluation," this word has emerged as one of the most frequently used ones in the cluster sustainable development of this sector. The results of this study indicate that subjects related to dataset repositories, multi-criteria evaluation, rainwater collecting, crops, and irrigation, and results have further enumerated that India has the greatest potential in Q2. As a result, these themes are mainly central but sparsely distributed, and thus have a negligible impact on the field's growth of cropland suitability utilizing GIS. The fundamental and core research fields that serve as the field's cornerstones are included in the basic themes' quadrant. Keywords like "multi-criteria analysis," "topography," "AHP," "modeling," and "land suitability" are included in this instance's bubble. These keywords draw emphasis on the notion and prompt development of GIS-based cropland suitability. Additionally, some of the subjects within these themes are required to advance the area of GIS-based land suitability, as evidenced by the way the themes appear to be evolving while still intersecting with the core themes. Finally, study areas that are either gaining traction or losing significance over time are captured by the emerging or declining themes quadrant. Words like "AHP" and "agricultural land suitability" are associated with two bubbles in this quadrant.

Three main groups were formed by arranging study areas related to scientific production according to time intervals estimated in years (Figure 14). Strong evidence of the differentiation, integration, transfer, and regeneration of themes may be seen in the intricate relationships between the many thematic evolutions and the diverse spectrum of study themes across time. It is possible to emphasize how topics combine or divide into multiple themes using these longitudinal analyses (Aria & Cuccurullo, 2020). The qualities of the lines indicate the caliber of the connections between the keywords. Research subjects can be arranged into motor and basic themes using the map of the thematic progression of scientific production (Melega, 2022).

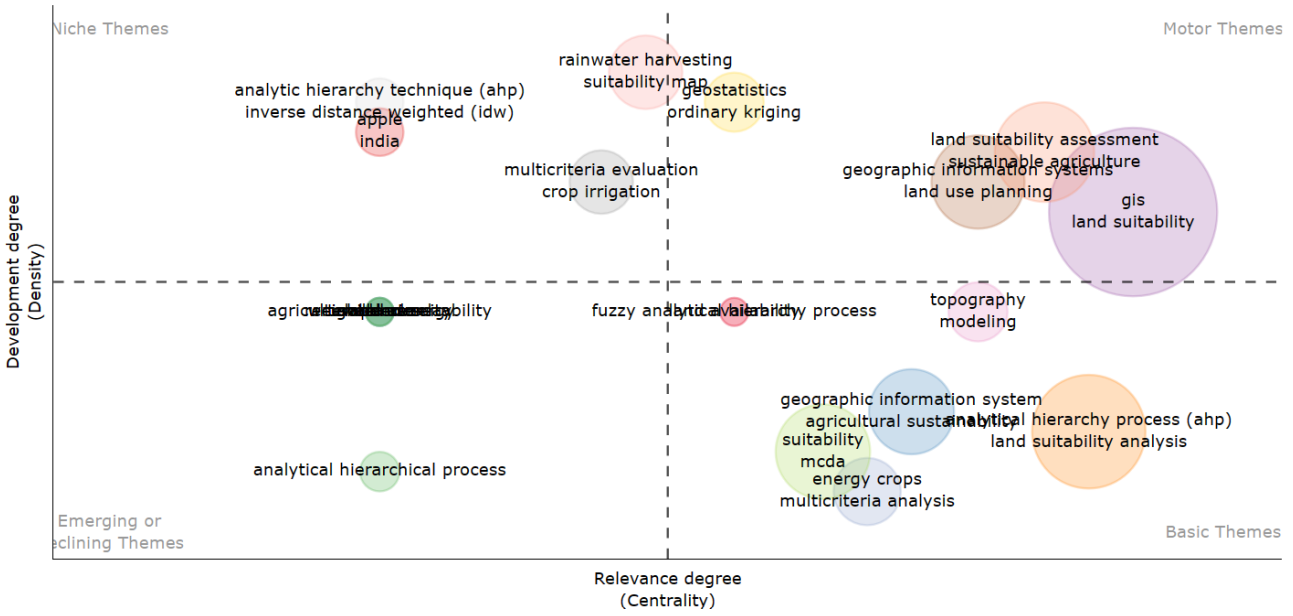

***Figure 13**. Thematic Map*

Suitability evaluation, suitability analysis, the hierarchy process, and remote sensing are the most common topics in the first phase (2010–2018), which makes sense given that research was still in the early stages of trying to define and clarify the idea at this time. The study on the subject is divided into multiple themes throughout the second phase (2018–2020). The early growth stage concentrated on decision analysis in this context and the expansion of land suitability and cropland. The study "Development of a Model Using Matter Element, AHP, and GIS Techniques to Assess the Suitability of Land for Agriculture" by Seyedmohammadi et al. (2019) was one of the most cited articles in the second phase, with 114 global citations. The study looked

at the suitability of land for barley production in the Dasht-e-Moghan region using a new framework that integrates the matter element model, AHP, RS, and GIS. Parts of the themes from 2021 and 2023 continue, including the AHP, GIS, and land suitability assessment. Furthermore, MCDA for cropland suitability analysis emerged as a prominent research topic in this phase of the GIS-based study, which focused on applying AHP. A great deal of research has also been conducted on cropland to assist in the development of sustainable land development and food production. For instance, in the Tozanlı subbasin, which is situated in the upper region of the Yesilırmak Basin in Turkey, Kılıc et al. (2022) investigated land suitability for wheat cultivation and created a land suitability map for wheat by combining the AHP-Fuzzy algorithm with GIS. Also, the research field's evolution and history were explained through the utilization of keywords and topic evolution. It is noteworthy that compared to earlier times, a significantly greater number of publications were published in the years 2019–2023.

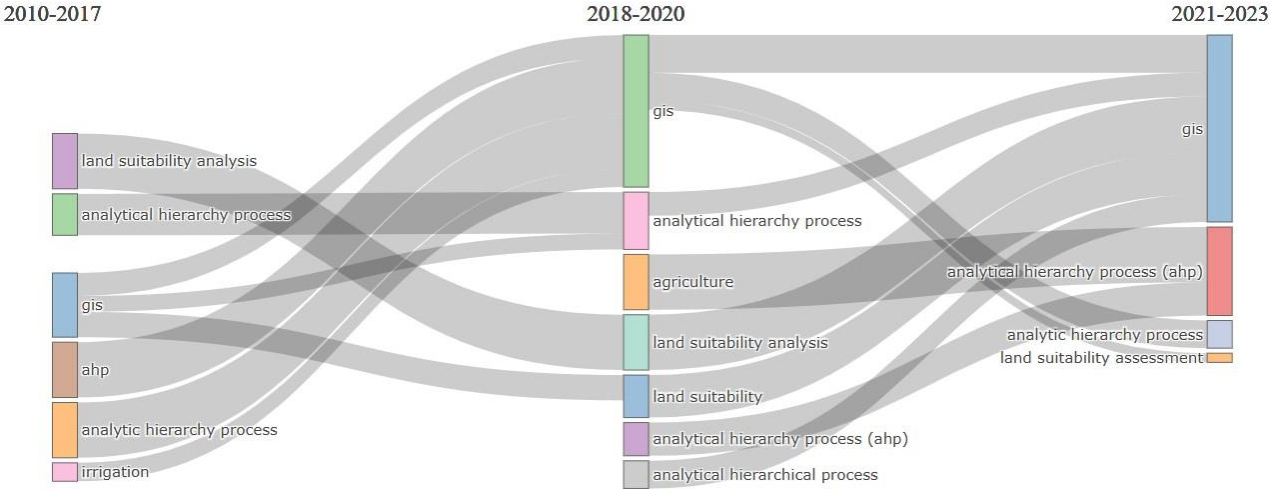

Figure 14. *Thematic Evolution of GIS-based CropLand Suitability from 2010-2023*

4. DISCUSSION

The major goal of this study was to comprehend the state of the literature and the patterns of recent publications in the field of GIS-based cropland suitability analyses. The study uses bibliometric analysis as a method of data analysis to explore the literature from the last ten years to achieve this goal. The topic has gained significance since the sector has seen an increase in global concern over the past ten years. The growing number of articles in this field of study amply demonstrates the significance and pertinence of this subject in the field. 183 publications that were published in 116 journals between October 2010 and October 2023 were included in the study. There has been an increasing tendency in the number of documents, particularly after 2019. In recent years, there has been an upsurge in research on site selection (suitability) issues utilizing GIS-MCDA in conjunction with the AHP techniques. AHP is frequently used in multi-criteria decision-making to establish the relative weights of each criterion. An instrument for pairwise comparison of the several criteria and sub-criteria taken into account for site selection issues is offered by AHP (Wigati et al., 2019). The relative importance of two criteria and the degree to which one criterion supersedes the other are determined via comparison. To determine each criterion's weight, a diagonal comparison matrix is created (Wigati et al., 2019). Research on AHP and GIS-integrated agricultural land suitability had not been done much until 2018, but since then, there has been a trend of presenting this type of data. Also, the contribution of researchers in countries like Croatia, Japan, Iran, and Peru is high for this kind of analysis. Conducting research in this field through high-level universities like the University of Tsukuba and Islamic Azad University has also been a factor in determining the productivity of the researchers as well as the field. Local citation and global citation factors have also had a positive impact on several types of research during the selected study period. Through that, the appropriateness and effectiveness of those researches are directly integrated into other research and it also contributes to the development status of this context. It is also unique that most of the articles selected for the study have been published in Journals with a 3.3 Impact Factor such as Sustainability. The journal

Sustainability (Switzerland) focuses on interdisciplinary studies related to sustainability, which aligns well with the themes of GIS-based AHP and cropland suitability. This alignment encourages researchers to publish their work in this journal. Publishing in a reputable journal like Sustainability (Switzerland) ensures high visibility and impact for researchers. The journal's emphasis on sustainability-related research attracts contributions that address critical global challenges.

Furthermore, the majority of the research has been conducted in developing nations, mostly in Asia, demonstrating the necessity of food production in these areas. AHP and GIS were the most often utilized site selection techniques, indicating their efficacy in identifying appropriate areas for cropland suitability. Decision rules aid in the evaluation of potential options for selection by helping decision-makers determine which ones are most appropriate. Although the applications of AHP and GIS have become popular tools for site selection, it is crucial to recognize that their efficacy may depend on several contextual factors (Subagyo et al., 2023). The growing body of studies on the best places to locate farms represents a step in the right direction toward more crop production and sustainable land development. Land sustainability in productivity can be addressed on a regional scale by researchers, politicians, and decision-makers by concentrating on these topics. The aforementioned study emphasizes the significance of implementing a comprehensive strategy that takes into account both the technical viability and wider socio-economic and environmental consequences. There needs to be more discussion on GIS spatial analytic modeling for land suitability, according to the vast number of academic papers. The results show that a large number of public universities have been instrumental in the advancement of GIS-based research. China, Japan, India, and Iran are home to the bulk of these colleges and universities. This suggests that GIS aids in the growth of nations with sizable economies and advanced technological sectors. The findings demonstrate that a co-occurrence network is useful in revealing the relationships between the frequently occurring keywords in a word cloud, in addition to helping to identify them. The more frequently occurring terms are larger and more apparent in the word cloud presented in Figure 15, whereas the less frequently occurring terms are smaller. Word clouds can be used to find the midpoint of written letters (Atenstaedt, 2012). Examining the keywords that writers use in their articles is a crucial method for learning about trendy topics and areas of interest for academics. With the aid of the most often used terms, word cloud analysis makes it possible to swiftly determine the publication's topic and concentration. Also, through the use of size and color, a word cloud converts texts into tags—words whose relative importance may be seen in the resultant cloud (Mulay et al., 2020). When these keywords are further examined, it becomes clear from their color code that the larger keyword (represented by its width) is related to the smaller keywords in a coordinated way. Choosing author keywords has the primary benefit of offering insight into popular subjects and emerging research trends. The GIS-based cropland suitability analysis, which is the main focus of this study, has a strong association with the analytical hierarchy process, multi-criteria analysis, GIS, and cultivation.

4.1. Trend Analysis

Numerous studies have focused on a new objective for text processing and data exchange once it was examined. Every year there has been a rise in the quantity of research articles as well; initially, they were centered upon AHP and MCDA, but now they include a larger range of cropland suitability topics. About problem structuring, element representation, quantification, linking parts to overarching objectives, and alternative solution evaluation, the AHP offers a reasonable and thorough framework (Saaty, 1980). The study's research trends show that there is an increase in cropland suitability based on GIS research data sources, as well as an expansion of application areas and a diversification of research methodologies. The intersection and integration of several disciplines will probably become a major trend in cropland suitability research in the future, and this field's application to the environmental background will likely grow wider. More research and analysis of GIS and AHP-based suitability analysis were suggested by the study. Policymakers, academics, researchers, and decision-makers should concentrate on developing early intervention techniques and raising essential awareness. On the other hand, numerous methods can be used to conduct a bibliometric analysis for the current study. Other than the ones employed in this work, future researchers can apply bibliometric techniques to obtain new and improved insights into this topic. Developing more sophisticated bibliometric analysis technologies in the future could enable the coverage and visualization of more parameters.

Figure 15. *Cloud Illustration of the Keywords*

4.2. Future Research Direction

Figure 16 displays the themes that are currently in trend as well as possible future advances in the discipline. Author-defined article keywords typically relate to this type of publication material and are adequate to extract subject elements of a field (Aria & Cuccurullo, 2017). Also, larger circles indicate more instances of the topic, while the circles on the lines show the number of occurrences of the topic (Ma et al., 2023). This research provides further context for the themes that have emerged over time about keyword occurrences in the literature on cropland suitability, AHP, and GIS. These topics may have various connections to the appropriateness of agricultural land. For example, within the issue of GIS-based cropland suitability in 2020, the most talked-about topics were "land suitability" and "GIS." Throughout 2018, themes like fuzzy logic and GIS were linked to the appropriateness of cropland based on GIS. Another important factor that has been emphasized since 2021 is the AHP and suitability. AHP, MCDA, and GIS scopes are likely to be given more attention in cropland suitability analyses. It is possible to confirm the efficiency and appropriateness of the analysis through these keywords in the period selected for the study. This can be described as one of the most prominent and productive areas of GIS-related research that is steadily growing. In the year 2023, the keyword "Climate change" has been discussed in several researches under a frequency of 10%. With the development of several keywords under trends topics in such research, the trend of such effective research is increasing. Effective goals can be reached with the use of such scientific methods in increasing the trend of future research directions.

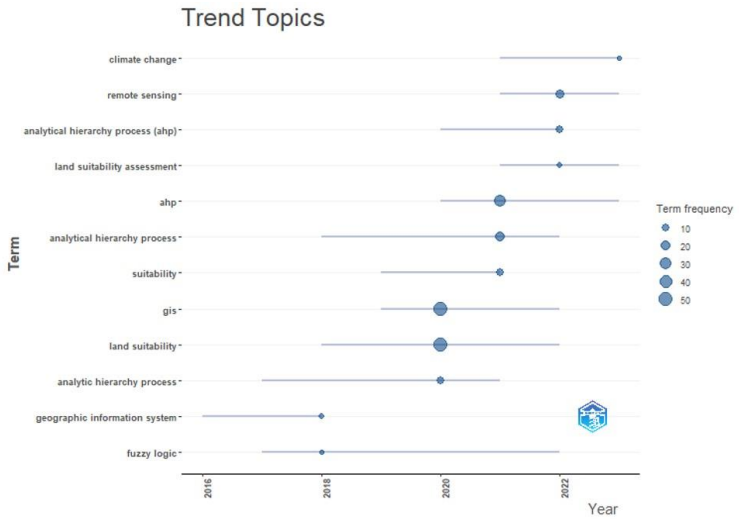

Figure 16. *Trending Topics*

5. CONCLUSION

Using Biblioshiny and VOSviewer, a comprehensive bibliometric analysis of the growth and evolution of GIS-based cropland suitability was conducted in this study using 183 papers from Scopus that were published over the last 23 years. Significant trends were found in the bibliometric examination of appropriate places for cropland utilizing AHP and GIS techniques. Preliminary findings, future directions for researchers, and gaps

in the literature concerning site selection and evaluation issues taken into consideration for cropland are all examined. The number of papers has increased, indicating a notable increase in research interest in recent years. The research papers' integration of diverse methods and approaches within planning disciplines has been accelerated by advancements in GIS and AHP. GIS is now a key component of this field's objective decision-making process due to the explosion of big data in data-driven studies. Researchers are conducting various research in the developing world of technology. At a time when an expanded research environment is being implemented through GIS, a growing impact has been added to the agricultural fields through selected studies. Through the use of multi-criteria methods, the yield and success of crops depend on such selected criteria. The productive environment of a cropland can in any way affect the variety of crops and its suitability to establish a successful plantation can be determined. The suitability of several criteria can be checked through AHP-MCDA in determining a suitable land for growing an agricultural crop. In this research as well, researchers using such methods have identified it as an effective tool. The selection of suitable and unsuitable areas for an agricultural crop depends on various environmental and soil criteria. Distribution of related crops can be conducted according to geographical regions. The researchers have presented whether it is possible to decide a way that the relevant criterion is suitable for the land through multiple decision analysis and the yield of the crop can also be determined according to the appropriateness of those criteria. Primarily, researchers have focused on the extent to which the hierarchical process in GIS and AHP can be used to select a suitable site. When it comes to the scientific development of systematic literature evaluations on cropland suitability using GIS, the Journal of Sustainability is a pioneer. India was the country that produced the most publications. Iran has the highest level of multi-country publication with other countries regarding the analysis of the corresponding Author's country, with the bulk of studies being single-country publications. Subsequent studies ought planners to embrace GIS as a crucial methodological technique in diverse land use procedures for multi-criteria decision analysis and decision-makers. For decision-makers, researchers, and practitioners involved in developing cropland, it gives a methodical approach to site selection and offers insightful information.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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