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GLOBAL RESEARCH TRENDS IN GOOGLE EARTH ENGINE FOR AGRICULTURE AND IRRIGATION: A COMPREHENSIVE REVIEW AND BIBLIOMETRIC ANALYSIS

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ABSTRACT

This bibliometric analysis explores the evolution and impact of Google Earth Engine (GEE) publications on agriculture, focusing on the period from 2014 to 2023. Leveraging the Dimensions database, the study explores deeply into the rise of GEE-related articles and their contributions to diverse scientific domains of agriculture. The analysis examines the evolution of GEE articles over time, principal authors, worldwide collaboration networks, important themes, and influential publications. The findings reveal a 98% rise in GEE publications, particularly in the last five years, with Remote Sensing being the leading journal, followed by Sciences of the Total Environment. China and the United States are at the forefront of international collaboration, contributing to 34% of research articles and receiving 40.54% of citations. The keywords "Sentinel," "random forest," and "NDVI" are the most often used terms in the context of satellite imagery, machine learning algorithms, and the index used for classification. They have been used 561, 411, and 265 times, respectively. The study emphasises the dynamic and influential properties of GEE in many agricultural domains that can guide future studies.
***Keywords*:** Irrigation, Google Earth Engine, Dimension, Agriculture, Bibliometrics, Remote Sensing.

Introduction

The number of Earth observation satellites has increased in recent years, resulting in a large influx of remote sensing data. NASA and the European Space Agency (ESA) have open data policies, so satellite observations from Landsat, MODIS, Sentinel-1, and -2 are shared with the world. This is to promote science and education (Pham-Duc *et al.*, 2017). Cloud computing systems with high-performance supercomputers store, compute, and analyse these satellites' massive remote sensing data for end users (Chi *et al.*, 2016). Google Earth Engine (GEE) is a growing online platform that can manage massive satellite data. Additionally, it is a versatile tool with applications in many fields (Velastegui-Montoya *et al.*, 2023). GEE's use of Google Earth Engine's repository makes environmental change and land cover dynamics analysis and visualization easy, making it useful for climate monitoring and biodiversity assessments (Gorelick *et al.*, 2017). GEE is flexible for geospatial analysis because to its wide range of satellite imagery categories, climate, weather, and geophysical datasets, and EVI and NDVI products. GEE is the remote sensing community's favorite cloud computing platform due to its free access, especially for developing regions, and many other benefits (Kumar & Mutanga, 2018). GEE is used in earth sciences and environmental studies to analyze land cover changes, ecosystem health, disaster monitoring, disease tracking, food security, and climate change consequences (Zhao *et al*., 2021). GEE's widespread application in earth and environmental sciences improves land use/cover, carbon emission, and environmental indicator mapping methods for sustainable development planning (Gorelick *et al.*, 2017).

Few academic studies evaluate and summarise GEE's capabilities and applications. The first review article on GEE system architecture was by Gorelick *et al.*, 2017. They examined GEE's main uses, problems, and future directions, as well as the platform's data catalogue and distribution strategies. Kumar *et al. 2018* examined 300 peer-reviewed articles published between 2011 and 2017. Their study examined GEE usage patterns, trends, and applications, focusing on whether developing country users were actively using the platform. Tamiminia *et al.*, 2020 examined 349 peer-reviewed papers between 2010–2019. The first meta-analysis and systematic review of GEE examined data, sensor type, study area, spatial resolution, application, strategy, and analytical methodologies. This extensive study sought to better comprehend Google Earth Engine's many applications and methods. Duan *et al.*, 2020 examined 450 peer-reviewed papers 2010–2020. A detailed review of GEE's datasets, functions, and pros and cons was their goal. The study examined Google Earth Engine's many uses in several sectors. Zhao *et al.*, 6 examined GEE and Google Earth (GE) trends and uses. The analysis included 565 peer-reviewed GEE articles and 1334 GE articles. A recent systematic assessment was examined on 343 high-impact scientific journal articles published in 2020–2022 Scopus and Google Scholar literature during the COVID-19 outbreak (Pérez-Cutillas *et al.*, 2023). Few papers on Google Earth Engine (GEE) and related topics were found in Google Scholar and WoS (Kumar & Mutanga, 2018; Tamiminia *et al.*, 2020 and Zhao *et al.*, 2021). Velastegui *et al.*, 2023 reviewed 2800 Scopus documents from 125 countries from 2011 to 2022 for a comprehensive bibliometric examination of Google Earth Engine (GEE), with China and the US leading. GEE's multidisciplinary value is shown by the intellectual structure analysis's topics of satellites, sensors, remote sensing, machine learning, and land use. The study highlights GEE's emerging position, ability to manage huge satellite datasets, and future research opportunities.

Dimensions is the most recent, having been established in 2018. Dimensions offer a single platform access to various types of research data (Herzog *et al.*, 2020). About 90 million papers with about 873 million citation connections were included in the debut edition of 2018 (50 million of which were full-text editions) (Hook *et al.*, 2018). However, more than 74,000 journal entries may be found in a newly released journal list by Dimensions (May 2020), demonstrating that Dimensions is a young and expanding database that also covers many smaller publishers (Singh *et al.*, 2021).

This study examines Google Earth Engine's visible evolution using the latest bibliographic data from the dimension database to identify its relationship to irrigated area mapping. Global collaboration networks involving researchers and countries and keyword co-occurrence networks are the main focus. Bibliometric analysis, proposed by Alan (Alan Pritchard, 1969), is one of the most effective methods for reaching these goals. The following questions were answered using bibliometric analysis.

1. How has the number of irrigation-related publications changed in GEE over time?
2. Which scientific journals and research institutions have been the main contributors to publishing studies on GEE and irrigation?
3. What is the structure of international collaboration networks between countries and scientists studying irrigation mapping with GEE?
4. Which articles in the field have had a significant impact on the community based on their citation counts?
5. How has Google Earth Engine (GEE) boosted research productivity and influence throughout Period I (2014-2018) and Period II (2019-2023)?
6. How have leading journals influenced the dissemination of GEE-related research, as shown in their content?

Materials and Methods

Box- 1: The search query string used in this study

TITLE-ABS-KEY (“Google Earth Engine” and “Irrigation” AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, “article”)) AND- (LIMIT-TO (LANGUAGE, “English”))

Systematic literature reviews employ a meticulous and transparent methodological approach to minimize bias in handling information, offering valuable insights into the research field (Fahimnia *et al.*, 2015 and Montalván-Burbano *et al.*, 2021). In a parallel manner, bibliometric studies utilize quantitative techniques to comprehensively explore the scientific output, enhancing our understanding of the field's features, development, and patterns (Ma & Ho, 2016). Utilizing bibliometric mapping involves creating a visual representation of a study area using networks to scrutinize its intellectual framework, components, and interconnections. This form of analysis was complemented by the study (Cobo *et al.*, 2011 and Herrera-Franco *et al.*, 2021). Bibliometrics has evolved into a crucial instrument embraced by researchers and widely acknowledged in academic circles (Donthu *et al.*, 2021).

Description of the methodology process

A four-phase methodological process was employed to conduct the proposed bibliometric analysis (fig.1).

1. **Search Criteria and Search procedure:** The study begins by delineating specific search criteria for bibliometric analysis, rooted in acknowledging Google Earth Engine (GEE) as a platform for processing satellite imagery, using search terms like "Google Earth Engine," and "Irrigation."(Gorelick *et al.*, 2017; Kumar & Mutanga, 2018 and Tamiminia *et al.*, 2020). The search procedure is implemented across selected databases in dimension to retrieve bibliographic information, emphasizing the need for reliable data sources (Andrés, 2009).

2. **Software Selection:** Software selection involves using Microsoft Excel for pre-processing and analysis of extensive datasets and VOSviewer Software for creating bibliographic networks (Taşkın & Aydinoglu, 2015). Additionally, this software facilitated the analysis of extensive datasets, performed calculations, and generated tables and graphs to assess the productivity of scientific output (Aqlan *et al.*, 2020; Kalantari *et al.*, 2017; Chandra, 2018; Abad-Segura *et al.*, 2019; and Payán-Sánchez *et al.*, 2021).

3. **Data Analysis and Trends:** Data analysis includes evaluating performance trends and examining intellectual structures through science mapping techniques, highlighting the roles of countries, universities, and authors, and visually representing research field interconnectedness. (Cobo *et al.*, 2011 and Donthu *et al.*, 2021). The initial aspect involves examining scientific production by analysing the development trends in publications and employing bibliometric indicators to emphasize the roles played by countries, universities, and authors (Baier-Fuentes *et al.*, 2019 and Montalván-Burbano *et al.*, 2021). This approach aims to visually represent the interconnectedness within the research field, employing keywords, authors, and journals to illustrate existing relationships (Duan *et al.*, 2020 and Zupic & Čater, 2015).

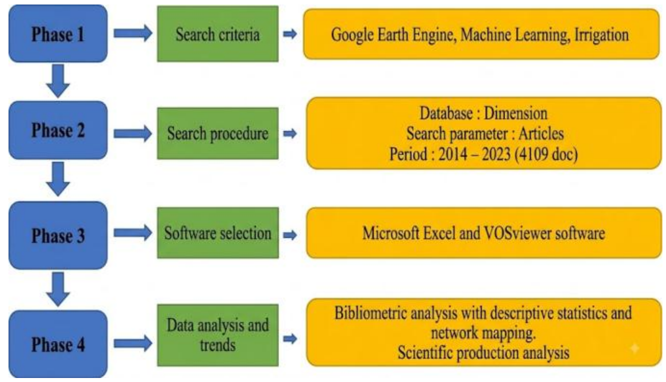


Fig. 1 : Flow chart for the Bibliometric analysis.

Results

General statistical information

The fundamental statistical details of the compilation of publications are presented in Table 1. Despite its official introduction of GEE in 2010, the initial publications delving into the application of Google Earth Engine emerged in 2014. The dataset comprises a collection of 4,109 original articles and review papers, spanning the period from 2014 to 2023. These documents have garnered a substantial impact, accumulating a total of 62,068 citations from 512 different sources. A notable characteristic of this scholarly output is the extensive collaboration among 10,828 authors. While 67 authors have contributed to single-author documents, the vast majority, 10,761, have participated in multi-author works. Interestingly, despite the collaborative nature of the research, a small fraction of 68 documents is single-authored. On average, each document has received just one citation, suggesting a broad impact across various topics, with an average of 25 authors contributing to each document. Furthermore, each author, on average, has been involved in the creation of five documents. This intricate interplay of collaboration, citation impact, and prolific authorship underscores the dynamic and multifaceted nature of the academic contributions within this dataset.

Scientific Publication

Figure 2 illustrates the upward trajectory in publication growth from 2014 to 2023 within this field of study. The inception of discussions regarding Google Earth Engine (GEE) can be traced back to an article focusing on the historical modeling of a city in 4D through GEE automation, marked as the initial document on the subject (Keller *et al.*, 2011). In that same year, the first glimpses of GEE research results surfaced in conference presentations (Kisilevich *et al.*, 2011) (Sun *et al.*, 2011).

The analysis of this field of study shown below in Figure 2 is categorized into two distinct periods: The analysis of this field of study spans two distinct periods: the Introduction phase from 2014 to 2018 and the Growth phase from 2019 to 2023. Period I, characterized by lower annual publication counts, reflects a learning curve in utilizing Google Earth Engine (GEE) in irrigation, with 218 publications and 1280 citations. In contrast, Period II exhibits a substantial increase in publications and citations, with 3238 publications and 58785 citations, indicative of diverse applications within the platform.

Table 1: Statistical information regarding the publications

Description	
Original publications (research papers from peer reviewed journal, review papers, book chapters, proceedings and edited books	4109
Citations	62,068
Period	2014-2023
Authors	10828
Authors of single-author documents	67
Authors of multi-author documents	10761
Single-authored documents	68
Average citations per document	01
Authors per document	25
Documents per author	5

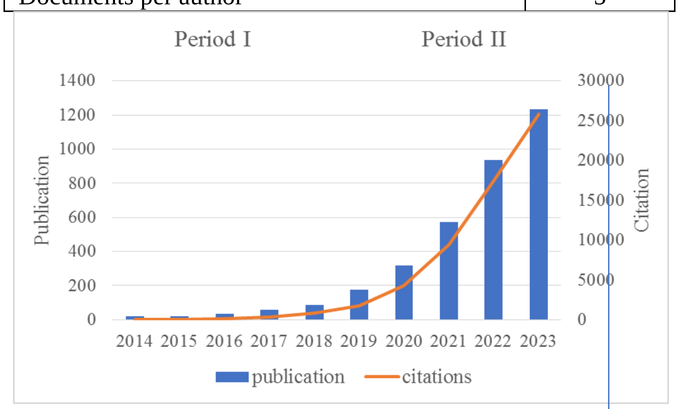


Fig. 2 : Number of scientific publications and citation over the year 2014-2023

Table 2: Top ten most productive countries based on the number of articles and citations

Order	Countries	Total Articles	Articles %	Total Citation	Citation %
1	China	825	20.6%	11508 (#2)	19.13%
2	United States	539	13.4%	12880 (#1)	21.41%
3	India	239	5.9%	3032 (#6)	5.04%
4	Germany	154	3.8%	3098 (#5)	5.15%
5	Australia	150	3.7%	3564 (#3)	5.92%
6	Iran	122	3.05%	1679 (#9)	2.79%
7	Italy	121	3.02%	3295 (#4)	5.47%
8	United Kingdom	120	3%	2665 (#7)	4.43%
9	Spain	97	2.4%	2164 (#8)	3.59%
10	Brazil	93	2.3%	1405 (#10)	2.33%

International cooperation among nations

The findings from search revealed that researchers from 116 different countries have contributed to the publication collection. Table 3 highlights the leading ten nations in terms of productivity, considering both the number of articles and citations.

The above data in table 3 offers insights into the global distribution of research articles and their corresponding citations, highlighting the contributions of various countries. China leads the list with 825 articles, comprising 20.6% of the total, and is second in terms of total citations with 11,508, representing 19.13%. The United States follows closely with 539 articles, constituting 13.4% of the total, and takes the top spot in total citations with 12,880, making up 21.41%. India holds the third position with 239 articles, contributing 5.9%, and ranks seventh in total citations with 3,032, representing 5.04%. Each country's total citations and their respective percentages further illustrate the global impact of research from these nations, reflecting the diverse and widespread nature of scientific contributions across different regions.

A visualization of the international collaboration network between countries which published at least five articles is shown in Figure 4, a collaboration network among countries is depicted, consisting of 75 nodes, organized into 7 clusters, and connected by a total of 2764 links. In this representation, every node corresponds to a country, and the size of each node is directly proportional to the number of publications associated with that country. Meanwhile, the thickness of the connecting lines between nodes is indicative of the level of collaboration strength between the respective partner countries. The collaboration network centres on the China and USA, emerging as the primary contributors. Notably, these two countries occupy a central position in the network. The collaboration dynamics among partner countries give rise to seven distinct clusters, each denoted by a unique colour code.

Collaboration among scholars

Figure 5 illustrates the international collaboration network of 148 scholars who have authored a minimum of five publications related to GEE. In this representation, individual scholars are represented by nodes, and the size of each node is directly correlated with the number of publications and citations associated with the respective scholar. The thickness of the connecting lines between nodes reflects the strength of collaboration among scholars, determined by the number of articles on which they have collaborated as co-authors. Scholars who are part of the same research teams are grouped within clusters, distinguished by different colours

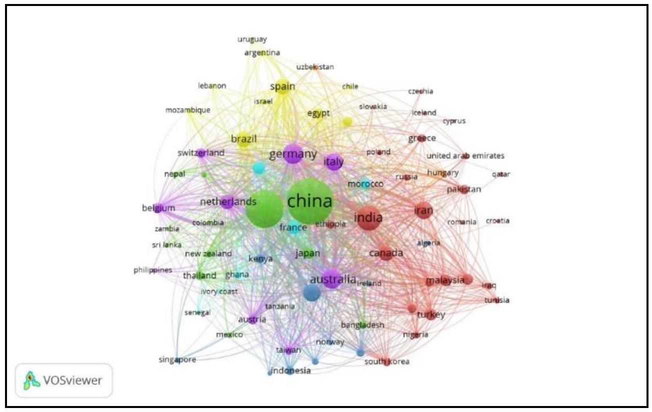
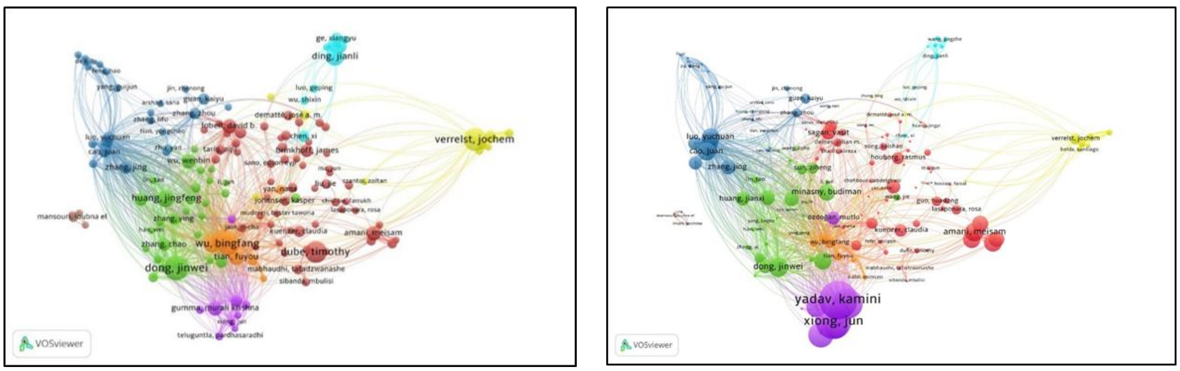


Fig. 3 : Illustrates global partnerships among countries.



(a) (b)

Fig 4: An international collaboration networks. (a) represents the network based on the number of publications, while (b) depicts the network based on the number of citations.

Table 3: Top ten scholars based on the number of articles.

Order	Author	Institution/ Country	Articles	Citations
1	Dong J.	Institute of Geographic Sciences and Natural Resources Research, China	17	554
2	Wu B.	Aerospace Information Research Institute, China	16	292
3	Verrelst J.	University of Valencia, Spain	16	289
4	Dube T.	University of the Western Cape	15	131
5	Zeng H.	Aerospace Information Research Institute, CAS.	14	260
6	Ding J.	Wuhan University	13	159
7	Huang J.	Zhejiang University	12	395
8	Zhang M.	Chinese Academy of Sciences, Beijing, China	12	196
9	Tian F.	Aerospace Information Research Institute	11	218
10	Gumma M.	International Crops Research Institute for the Semi-Arid Tropics	10	570

Table 3 and Table 4 provide valuable insights into the scholarly contributions of researchers in the field of GEE and irrigation, with a focus on the top ten scholars based on the number of articles and citations, respectively. In Table 3, Dong J. from the Institute of Geographic Sciences and Natural Resources Research in China secures the top spot with 17 articles and 554 citations. Wu B. from the Aerospace Information Research Institute in China and Verrelst J. from the University of Valencia in Spain closely follow with 16 articles each, accumulating 292 and 289 citations, respectively. The list further includes researchers from diverse institutions such as the University of the Western Cape, Wuhan University, Zhejiang University, and the Chinese Academy of Sciences, showcasing a global distribution of contributors.

Table 4, on the other hand, highlights scholars based on the number of citations they have garnered. Yadhav K. from the University of New Hampshire takes the lead with 1,200 citations across 8 articles.

Xiong J. from the China Academy of Engineering Physics and Congalton R. from the University of New Hampshire follow closely with 1,125 and 925 citations, respectively. Gumma M. from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India appears in both tables, emphasizing the significance of his work, as they secure the 7th position in terms of citations with 570, while ranking 10th based on the number of articles with 10. These tables collectively underscore the prolific output and impact of researchers from various institutions and countries, contributing significantly to the scholarly landscape in the field.

Table 4 : Top ten scholars based on the number of citations.

Order	Author	Institution/ Country	Citations	Articles
1	Yadhav K.	University of New Hampshire	1200	8
2	Xiong J.	China Academy of Engineering Physics	1125	5
3	Congalton R.	University of New Hampshire	925	6
4	Teluguntla P.	Bay Area Environmental Research Institute	755	6
5	Thenkabail P.	United States Geological Survey	687	5
6	Oliphant A.	Texas State University System	662	5
7	Gumma M.	International Crops Research Institute for the Semi-Arid Tropics	570	10
8	Dong J.	Institute of Geographic Sciences and Natural Resources Research, China	554	17
9	Amani M.	Infrastructure Canada	533	10
10	Brisco B.	Natural Resources Canada	523	7

Analysis of Journal publishing the articles

An overview of the top ten journals given that have published the most articles related to Google Earth Engine (GEE), along with key metrics such as the total number of articles published, the percentage of articles contributed, and the total number of citations garnered, both in terms of the actual count and the percentage is presented in figure 6 and table 6. Topping the list is "Remote Sensing (RS)" from MDPI, publishing 411 articles, constituting 10.28% of the total articles in the dataset. The journal has also accumulated 6,568 citations, accounting for 10.91% of the total citations. Following closely is "Sciences of the Total Environment" from Elsevier, with 74 articles (1.85%) and 825 citations (1.37%). Sustainability from MDPI and "Remote Sensing of Environment (RSE)" from Elsevier occupy the third and fourth positions, contributing 61 (1.52%) and 60 (1.5%) articles, with 582 (0.96%) and 2,969 (4.93%) citations, respectively. The list also includes journals such as "International Journal of Applied Earth Observation and Geoinformation," "Water," "Computer and Electronics in Agriculture," "ISPRS Journal of Photogrammetry and Remote Sensing," "International Journal of Remote Sensing," and "Agronomy," each with their respective contributions to the field in terms of published articles and citations. These journals collectively represent diverse outlets for research related to GEE, with MDPI and Elsevier being prominent publishing houses in this domain.

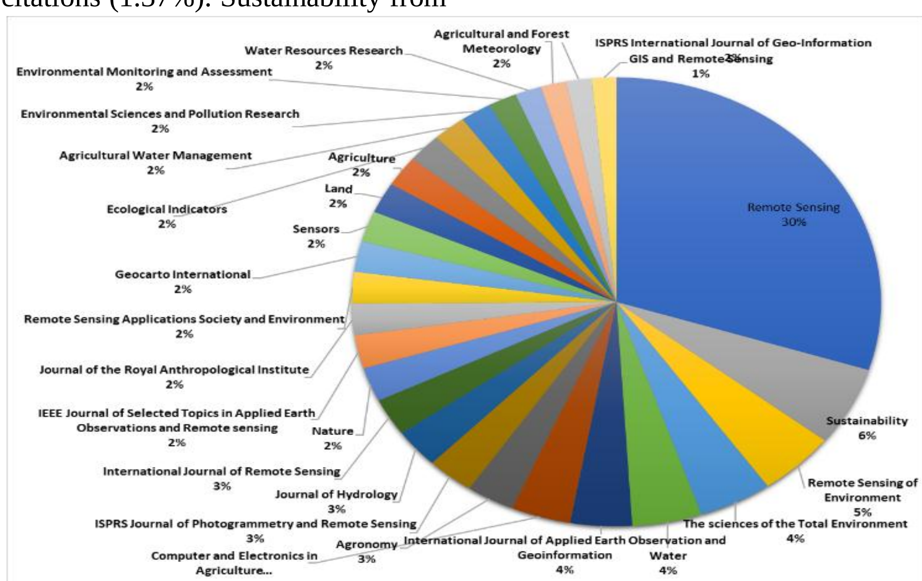


Fig. 5: Journals in which articles related to the application of GEE in irrigation were published.

Table 5: The top ten journals published the most articles related to GEE

Order	Journals	Publishing house	Total Articles	Articles %	Total Citation	Citation %
1	Remote Sensing (RS)	MDPI	411	10.28	6568	10.91
2	Sciences of the total Environment	Elsevier	74	1.85	825	1.37
3	Sustainability	MDPI	61	1.52	582	0.96
4	Remote Sensing of Environment (RSE)	Elsevier	60	1.5	2969	4.93
5	International Journal of Applied Earth Observation and Geoinformation	Elsevier	58	1.45	1205	2
6	Water	MDPI	54	1.35	481	0.79
7	Computer and Electronics in Agriculture	Science Direct	51	1.27	1056	1.75
8	ISPRS Journal of Photogrammetry and Remote Sensing	MDPI	42	1.05	1814	3.01
9	International Journal of Remote Sensing	Taylor and Francis	36	0.9	293	0.48
10	Agronomy	MDPI	35	0.87	446	0.74

Keyword analysis

The keywords used by authors for a publication significantly influence how the work is portrayed and communicated within scientific communities. Keywords analysis is a method used to identify overarching research patterns and focuses on compiling the keywords from all relevant papers within a specific field (Dixit & Jakhar, 2021). Table 6 displays the most keywords for each group. We reconciled inconsistencies by merging names that have the same meaning, for as "SVR" and "Support Vector Regression," or "NDVI" and "Normalized Difference Vegetation Index." The most commonly used machine learning method in GEE used in agriculture is the "Random Forest," followed by the "Support Vector Machine," and then the "Convolutional Neural Network (CNN)." Sentinel is the predominant satellite imagery source for agricultural spatial analysis, with Landsat being the second most utilized. Irrigated area mapping and crop mapping are prominent uses of Google Earth Engine in agriculture. The most utilized indexes for mapping are NDVI and NDWI (Normalized Difference Water Index).

The is the frequently used machine learning method used in GEE for agriculture is "Random Forest" (no of occurrence is 411). This is followed by the "Support Vector Machine", “Artificial Neural network (ANN)” and "Convolutional Neural Network (CNN)" (no of occurrence 175 ,65 and 58 respectively). Landsat is the second most utilised satellite imagery source for agricultural spatial analysis, with Sentinel being the most widely used satellite imagery source. In the agricultural sector, two of the most common applications of Google Earth Engine are crop mapping, crop yield estimation, irrigated area mapping and watershed. For mapping, the NDVI and NDWI (Normalised Difference Water Index) are the indices that are utilized the most.

Table 6 : Most frequently used keywords

Keyword	No. of occurrence
sentinel	561
Remote sensing	480
random forest	411
google earth engine	372
agriculture	334
NDVI	265
Landsat image	156
spatial analysis	147
support vector machine	175
deep learning	111
artificial intelligence	94
machine learning model	90
artificial neural network	65
CNN	58
irrigated area	57
crop mapping	53
Crop yield	49
NDWI	35
watershed	28

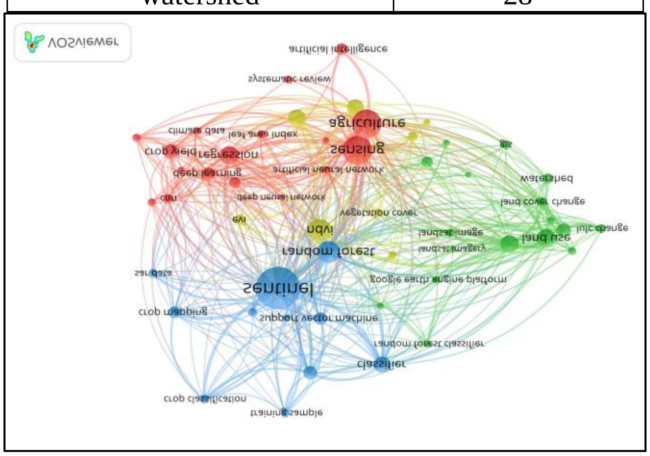


Fig. 6: Keyword co-occurrence networks

Analysis of the most cited articles

Table 7 represents the research articles with the highest number of citations in Google Earth Engine (GEE) related to agriculture mapping. For instance, the article titled "Sentinel-2 Data for Land Cover/Use Mapping: A Review," published in Remote Sensing in 2020, has authors from various institutions such as in Zambia, Sri Lanka, New Zealand, and Japan. This review article has been cited 274 times and provided an overview of the utilization of Sentinel-2 data for land cover and land use mapping using GEE. Another notable contribution is the article titled "Nominal 30-m Cropland Extent Map of Continental Africa by Integrating Pixel-Based and Object-Based Algorithms Using Sentinel-2 and Landsat-8 Data on Google Earth Engine." Published in Remote Sensing in 2017, this collaborative effort involves researchers from different institutions of USA and India. The article has been cited 270 times and presented a comprehensive cropland extent map for continental Africa. The third article, "Monitoring Rice Agriculture across Myanmar Using Time Series Sentinel-1 Assisted by Landsat-8 and PALSAR-2," published in Remote Sensing in 2017, involves researchers from different institutions across the globe. This research, cited 211 times, focused on the monitoring of rice agriculture in Myanmar using a combination of Sentinel-1, Landsat-8, and PALSAR-2 data. These articles contribute to the growing body of knowledge in the field of Remote Sensing and Geographic Information Systems. The affiliations of the authors from diverse research organizations and countries highlight the international collaboration and the global nature of research in this domain.

Discussion

The initiation of research and applications in GEE dates back 13 years, marked by a noticeable surge in scientific output. Although being established in 2010, GEE has only recently become popular, especially over the last five years, when nearly 85% of articles related to GEE have been published. The growth in Period II (2019-2023) is 98 percent more than in Period I (2014-2018), suggesting increased research productivity and impact, potentially due to factors like increased collaboration and development of programming skills by the researchers. The research employed five bibliometric maps as visual representations to analyse the intellectual structure of the study, providing relevant graphic insights into the topic. This research endeavour involved the participation of 125 nations. China holds the top position (20.6%), contributing the highest number of documents on the subject with 825 publications, while the United States (13.6%) follows second place with 539 contributions. Similarly, these nations lead in the production of collaborative works, involving authors from different countries, focusing primarily on cropland mapping (Dong *et al.*, 2016) and irrigated area mapping (Huang *et al.*, 2017). The global collaboration network depicted indicates that China is actively investing considerable resources in the development of this emerging research field. This is evident through the establishment of various research groups across several universities and public institutions. International collaboration among scholars and countries underscores the global nature of GEE research. Additionally, they engage in collaborative efforts with Canada, the United Kingdom, and Brazil. Furthermore, scholars from the top ten countries contributing to approximately 61.8% of the overall publications and 75.3% of the total citations. The majority of the scientific output is in the form of research papers, with Remote Sensing emerging as the journal with the highest number of publications. Top journals include Remote Sensing and Sciences of the Total Environment. Notable articles focus on topics like land cover mapping, cropland extent, irrigated area mapping etc.

Table 7: The top five articles received the greatest number of citations in journal of remote sensing.

Sl. no.	Title	Year	Authors/ Name of Research organization/Country	Times cited
1	Sentinel-2 Data for Land Cover/Use Mapping: A Review	2020	Copperbelt University; Rajarata University of Sri Lanka; Scion; University of Tsukuba, Japan; New Zealand; Sri Lanka; Zambia	274
2	Nominal 30-m Cropland Extent Map of Continental Africa by Integrating Pixel-Based and Object-Based Algorithms Using Sentinel-2 and Landsat-8 Data on Google Earth Engine	2017	Xiong, Jun; Thenkabail, Prasad; Tilton, James; Gumma, Murali; Teluguntla, Pardhasaradhi;	270
3	Monitoring Rice Agriculture across Myanmar Using Time Series Sentinel-1 Assisted by Landsat-8 and PALSAR-2	2017	Torbick, Nathan; Chowdhury, Diya; Salas, William; Qi, Jiaguo	211
4	Mapping Three Decades of Changes in the	2020	Amazon Environmental Research Institute, Brazilian	123

	Brazilian Savanna Native Vegetation Using Landsat Data Processed in the Google Earth Engine Platform		Institute of Environment and Renewable Natural Resources; Stockholm Environment Institute; Brazil; Sweden	
5	Mapping Winter Crops in China with Multi-Source Satellite Imagery and Phenology-Based Algorithm	2019	Henan University; Institute of Remote Sensing and Digital Earth; Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, University of Chinese Academy of Sciences**,** China.	119

The top scholars and countries contributing to GEE research further emphasize the international and collaborative nature of this field. The study demonstrates the dynamic and multifaceted nature of GEE research, with a substantial increase in both output and impact over the years. As noted in prior articles addressing journal preferences in satellite remote sensing-related fields (Hemati *et al.*, 2021 and Pham-Duc & Nguyen, 2022), a significant portion of articles related to Google Earth Engine (GEE) was found in Remote Sensing. While the quantity of articles in Remote Sensing contributed a quarter to the overall publications. Notably, Chinese scholars demonstrated a strong affinity for publishing in Remote Sensing.

Sentinel and Landsat satellite imaging datasets are dominating because to their high resolution, free access, and near real-time data availability (Pham-Duc & Nguyen, 2022). The increasing significance and impact of GEE in the scientific community are underscored by its varied applications across different fields, international cooperation, and notable contributions from particular scientists and nations. Machine learning techniques such as Random Forest, Support Vector Machine, Artificial Neural Network, and Convolutional Neural Network are commonly utilised in Google Earth Engine (GEE).

Conclusion

Google Earth Engine (GEE) ensures uniform access to its resources and data for everyone. The comprehensive analysis of Google Earth Engine (GEE) publications spanning over 2014 to 2023 reveals a remarkable growth trajectory in both research output and impact. The dataset, comprising 4,109 articles, showcases a dynamic collaboration among 10,828 authors, reflecting the interdisciplinary nature of GEE applications. The research landscape witnessed two distinct periods, with Period II (2019-2023) marked by a substantial acceleration in both publications and citations, indicating heightened research activity and influence. The top journals, led by Remote Sensing, play a pivotal role in disseminating GEE-related research. Noteworthy scholars, such as Dong and Yadhav, contribute significantly to the scholarly landscape. The findings underscore the need for increased accessibility to GEE in developing nations and recommend initiatives for collaborative working to further enhance global participation in this evolving field. The multiplicity of applications showcases the versatility of GEE in various domains to tackle contemporary agricultural challenges such as yield estimate, crop mapping, and irrigation mapping. It may be pivotal in assisting us in achieving the development goals established for this millennium, particularly in the realm of agriculture.

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