

Mapping Research Trends in Satellite Imagery Applications for Agriculture: A Bibliometric Analysis

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Abstract – This research involves wide-ranging bibliometric research pertaining to the application of satellite images in agriculture from the late 1970s to the middle of 2025. Data from the Web of Science database were analyzed to understand the trends in publications, the patterns of citations, and the research in different parts of the world. Publications of different years were analyzed in order to understand the impact of major countries and to rank the journals based on productivity and impact. After 2017, there was a significant increase in research, and the USA, China and India were all major contributors in terms of the number of researchers and publications. Some study impact was not as good as expected based on the number of publications, while in others it was. The remote sensing field is largely dominated by IEEE journals which have a very high average citation rate per paper published.

Keywords – Satellite Imagery, Remote Sensing, Agriculture, Bibliometric Analysis, Citation Impact, Research Trends, Web of Science, IEEE Journals.

I. INTRODUCTION

The increasing intensity of urbanization, agricultural practices, and climate change is continually altering the perception of landscapes with which persons globally engage every day. Given the continuous nature of these changes, it is essential to comprehend how both people and communities perceive and interpret their environment. Community perception and enjoyment of a landscape significantly influence the adoption and efficacy of land management initiatives [1].

The availability of the satellite EO (earth observation) information and the development of the cloud computing infrastructures always open new opportunities to address different challenges by delivering crop-specific information about specific land parcels to the national level with the help of various cropping models [2]. The basic information provided by EO is the yield forecasting and crop location, which is vital in stabilizing the market, mobilizing the humanitarian intervention, and reducing the food supply problems.

The satellites contain multi-spectral wireless sensors that possess the ability to resolve, vital in establishing the agronomic and physiological nature of crops. Precision farming monitoring capability lies on the geographical and temporal diversity of crop and is dedicated to the strength of the satellite resolution. Satellite has time resolutions since satellites in the orbit are programmed with a schedule of the duration of time they can spend before going back to a similar geographical area after completing an orbit around the earth. Revolution is an important period to monitor the crisis and the phenology of crops including crop growth [3].

In addition to that, satellites have high spatial resolution in precision agriculture since farming landscape and fields are typically heterogeneous and have singularities and can be perceived in case the spatial resolution is high enough to distinguish particular objects. Spectral resolution is the number of bands and bandwidth or rather the reflected spectrum segments that can be observed by the satellite sensors and it allows observing several physiological properties of plants. Lastly, there is radiometric resolution defining the amount of data, which can be obtained by sensors. All the attributes of sensors depend on the physiological and agronomic properties of particular plants [4].

The satellite remote sensing has developed and transformed the way of the interpretation, assessment, and monitoring of the ecosystem at different levels. Over the past two years, the sphere has been subject to a tremendous development in the analysis of solutions, data processing approach, and sensor technology. It is possible to view the land cover, the dynamics of the oceanic processes, the state of the atmosphere, and the natural disasters better thanks to using modern satellites providing the high-resolution image and multi-spectral information. These activities have enhanced climate change modelling, city planning, disaster management and resource management. This pattern of integrating machine learning and AI has radically enhanced the precision and effectiveness of analyzing data and this has enhanced the new usage of predicting and assessing the environment [5].

In this study, we aim to evaluate the progress of global research integrating the deployment of satellite images within the agricultural sector. Our study is centered on publication review, citation distribution, and contributions made by major countries and top-tier publication in the field of agriculture.

The rest of the study has been organized using the following format: Section II provides a critical study of related work on technological developments, which include UAVs, remote sensing, and aerial imaging hyperspectral sensor, which are related to agricultural science. Section III discusses the data sources, data analysis approaches, and methodological limitations of our study. A detailed discussion of our results has been provided in Section IV, which describe the (i) global publication growth and nation-level study performance, and (ii) journal productivity, citation impacts, and authorship. Lastly, we conclude our study in Section V by summarizing the relevance of satellite imagery in boosting precision farming.

II. LITERATURE REVIEW

According to research in [6], satellite sensors have been used for remote sensing agricultural application since the 1970s when the first Landsat satellite with multi-spectral sensors was established. Since then, spaceborne multispectral sensors with medium or high spatial resolution have been extensively utilized by the remote sensing community for agricultural research, such as Landsat, Spot, Geo-Eye, World-View, Pleiades, and Sentinel. Multispectral data, including satellite and aerial photos, are often used to estimate spectral and geographical patterns of crop biomass using spectral indices, such as the NDVI (normalized difference vegetation index) and other vegetation indices.

AVIRIS is the hyperspectral sensor of an aerial imaging that was first introduced in [7] in 1990s. It was shown that new sensors had better spectrum resolution, compared to multi-spectral sensors. Consequently, they were able to give a lot of information regarding the vegetation being studied. Multi-spectral imagery is less expensive and older than hyperspectral photography, which is offering better spectral resolution, which is synonymous to high detection in vegetation analysis and surveillance.

In a research work by Lottering, peerbhay and adelabu, [8] the numerous uses of remote sensing in the different sciences including agriculture, earth sciences in the environmental sciences among others were established. Recent inventions in the field, machine learning algorithms and vision processing, have greatly enhanced the relevancy of data and correctness of data thus making it easy to make the accurate judgment in various fields of science.

The differences in the land mass cover are examined by Hejmanowska and Kramarczyk [9] by developing land user/cover area survey (LUCAS) database in which Sentinel satellite pictures are accessed. The effectiveness of various classification methods was also quantified by the review and the comparative evaluation of their degree of effectiveness was made in making the distinction of land mass cover classifications. The results stated that it was needed to combine huge amounts of data with understandable satellite images to strengthen the policy of monitoring the setting and ruling the earth. It has been observed that the accuracy of the climate information is enhanced as a result of the calibration and validation of geared structures of the surface-air temperatures as incorporated in the MODIS.

Nevertheless, Sham et al. [10] altered these models and strengthened the dependence on the assessment and forecasting of climate patterns by means of elaborate ground-based measurements. The use of remote sensing has been enhanced by the progress in image analysis. Moreover, Shree, and Narayan [11] suggested a framework of mixtures and non-linear diffusion to reduce the level of noise in SAR imaging in order to improve the quality of information and its utilization. Such innovations are needed in any application where precision of satellite data is demanded such as evaluation of infrastructure, sewerage and disaster management.

In contrast to a research study conducted by Brisco et al. [12], remote sensing developments have been established to be a viable aspect in enhancing crop management in precision farming. The authors evaluated how the soy beans were affected by nematode infection using a multi-spectral imaging and ML techniques on air. Among the outcomes, the possibility of AI to determine the stress of crops and provide the appropriate interference to minimize economic losses, and improve the productivity is mentioned.

Sishodia, Ray and Singh [13], on the other hand, surveyed machine learning methods used to distinguish lithological improvements in the Khyber Range which highlights the effectiveness of satellites in geological exploration and mineral distribution. Implementation of the integrating method that combines the satellite data with the ground-based observation

facilitated a spatio-temporal study of heatwaves that developed perceptions about high temperature trends and identical implication on the climatic adaptation processes.

As described by Adão et al. [14], the use of multispectral and hyperspectral satellite and aerial photography in agriculture is prevalent; however, such data are restricted to cloud-free days, and their spatial and temporal resolution may be inadequate. Consequently, the efficacy of using satellite and aerial data may be inadequate. An alternative to satellite and aerial photography for agricultural use was proposed: Unmanned Aerial Vehicles (UAVs). UAVs provide significant promise for applications in crop management and precision agriculture because to their capacity for rapid and repetitive deployment. Moreover, UAVs may operate at many altitudes and, unlike satellite and airborne observations, they do not have observation gaps stimulated by significant cloud cover or other climate conditions, nor are their coverage areas restricted by orbital limitations around the Earth.

Cruz [15] conducted a study on agricultural science and concluded that education is fundamental for facilitating sustainable agriculture. By using ecological stewardship and agro-ecology concepts into curriculum, academic institutions may educate learners on biodiversity, resource efficiency, and soil health. Learners with this education are more prepared to employ regenerative methods, which enhance environmental resilience and mitigate the adverse impacts of conventional agricultural approaches. In addition, agricultural education nurtures a culture of progressive learning, enabling experts in the agricultural field to be informed about the recent scientific developments and optimum actions. The current condition of agricultural science education integrates various learning tiers and involves advancing pedagogical methods and the curriculum.

According to Zhang and Zhang [16], developments in AI, specifically in computer vision, are significantly encompassing the ability of remotely sensing dataset. Supervised machine learning methods depend on large-scale training samples in order to calibrate models required to forecast unidentified data with an uncertainty level. While this has significant applications in still pictures, such as object detection in photos, the same methodologies have been effectively used with spatially explicit remotely sensed data. For example, delineating the scope of cocoa plantations in Ghana and Ivory Coast, crop categorization, oil palm analysis, and identification of forest degradation, among many others.

These strategies are economical and beneficial, particularly in regions where observational data are insufficient. The cocoa plantation mapping research conducted by Sabas et al. [17] demonstrated both the area of cocoa plantations in the two nations and their contribution to forest loss.

III. METHODOLOGY

Data Sources and Selection Criteria

Data was primarily retried from the WoS (Web of Science), a credible academic database populated with a variety of peer-reviewed articles from the highest ranked journals in multiple fields of study. WoS was chosen for its extensive coverage in bibliometric research as it provides the necessary in-depth citation records, detailed affiliations of the authors, and total numbers of publications for a given research area. Because this study relies heavily on citation analysis as one of its main methodologies, WoS is best suited to monitor and visualize the research on the utilization of remote sensing imagery in agriculture.

The analysis covers the span of research published from 1977 until the middle of 2025, thus giving enough time for the evaluation to reflect on almost 5 decades on research output over. This time span is a result of a balanced consideration of the satellite image research in agriculture over the past decades and the most recent exponential increase of published study materials on the subject especially after the year 2010. The references included in the based study was restricted to articles that specifically discussed the application of satellite images in agriculture as ascertained from a key word search on the basis of the following, remote sensing, satellite images, agriculture and geospatial technologies. In the effort to shape the research output to reflect the research vacuum in the domain, articles that were too distant to the research focus were disregarded as well as non-peer reviewed articles.

To preserve the visibility and quality of the output, only articles from indexed journals were included in the dataset. The articles that were retained in the dataset therefore meet the publication and subject matter eligibility.

Data Analysis Techniques

In order to analyze the collected data, a number of bibliometric techniques were utilized, emphasizing the analysis of publications' frequency, tracking citations, and classifying countries and journals according to their research and impact.

Publication Frequency Analysis

We employed this method to analyze the number of annual publications identify trends over time. Tracking the number of published works from 1977 to 2025 gave the research a period to grow and decline in research stagnation to work this hypothesis. After the increase from 2017, more time was used to develop published works. **Table 1** provides the number of publications in a given research year and to show the highest years in research production.

Table 1. Number of Publications Each Year (1977 Through the First Half of 2025)

Year	1977–1990	1991–2000	2001–2010	2011–2020	2021–2025
Publications	X	Y	Z	A	B

Citation Tracking

Over time, publications have had certain academic impacts which thoroughly tracked the means by which publications had been researched. Several publications and studies analyzed the extent to which satellite imagery research in agriculture advanced. The study calculated the average number of citations across the entire dataset and citations were counted per paper. This study, in estimation, helped distinguish highly impactful publications from those which had been cited a little more than. To visually capture the disparity of the published research and the cited research, a box and whisker plot were used, which showed the range of the cited research from different countries.

Country and Journal Ranking

Based on the total research output and the respective headcounts of the research personnel, the countries were given rankings. Moreover, the rankings were separated by the number of references to other work, and thus were able to quantify, as well as qualify, the research. A ranking by publications, in the same manner as the journals, was also completed, and the individual journals were assessed by their average number of citations to quantify their impact. The rankings have been displayed in **Table 2** and **Table 3**.

Table 2. Top 10 Countries by Number of Publications (1977-Mid 2025)

Rank	1	2	3	4	5	6	7	8	9	10
Country	USA	PRC	India	Brazil	Italy	Germany	Spain	France	UK	Pakistan
Publications	400+	200+	150+	120+	100+	90+	80+	75+	70+	60+

Table 3. Top 5 Journals by Number of Publications (1977–mid 2025)

Rank	Journal Name	Number of Publications
1	International Journal of Remote Sensing (IJRS)	307
2	International Journal of Applied Earth Observation and Geoinformation (IJAEOG)	157
3	Computers and Electronics in Agriculture (CEA)	107
4	IEEE Geoscience and Remote Sensing Letters	85
5	Agricultural Systems	72

Limitations of the Methodology

While the methodology has strengths, it also has weaknesses that need to be considered. Perhaps the biggest of these weaknesses has to do with citation. Citation patterns differ by area of the world and by discipline. For example, some countries have more academic collaborations and more available funding, thus they have higher citation. Other countries have less of an ability to publish in high-impact journals or have their work recognized at the global level. This will lead to some countries with a large academic infrastructure to have an exaggerated sense of their impact, while researchers in poorer countries will have their work contributions undervalued.

Another limitation is the WoS database. While WoS is one of the best available sources for bibliographic research and analysis, it is not comprehensive and does not include many sources, especially those in languages other than English. This could lead to their being a lack of representation of the output of research published in other countries that do not have English as their primary language. In addition, other pertinent journals not sampled by the database could be more widely published and this would lead to a lack of representation of the global volume of research output.

To address these weaknesses, the research reviewed only those countries with a significant number of publications, specifically those who published more than 80 papers in the time frame of the research. This guides the research in a direction that is most informative, ensuring that the analysis is not skewed by insignificant countries. Furthermore, during the timeframe of the research, only journals that were uniformly indexed by WoS were included, which guarantees that the most prestigious and reputable journals with the highest rank in the discipline are reflected in the dataset.

IV. RESULTS AND DISCUSSION

Global Publication Growth and Country-Level Research Performance

An analysis of the annual publication count from 1977 to mid-2025 see **Fig. 1** reveals a significant increase in publications over the last 20 years. Since 2017, the annual number of journal articles has exceeded 100, with the trend intensifying in 2025, as 130 research articles were released by mid-year. The USA is the most prolific nation over the timeframe of our research, with more than 400 articles see **Fig. 3**. India and the PRC (People's Republic of China) rank second and third, respectively, with over 200 and 150 published scientific publications. Within a more isolated cohort, some European nations, namely Germany, Italy, and Spain, exhibit less than 150 articles.

Analysis of the data by decade see **Fig. 2** reveals that the USA maintained its status as the preeminent nation for three decades (1991–2000, 2001–2010, 2011–2020) until being surpassed by the PRC in 2021–2025. India was rated second from 1991 to 2010, thereafter dropped to fourth from 2011 to 2020, and has lately ascended to third position. Italy has ascended from 7th to 4th position, but England has progressively fallen out of the top 20. Countries such as France and Germany

consistently maintain places inside the top 10 throughout the time. Data from 1977 to 1990 are omitted because of the fewer number of publications.

The ranking of researchers engaged in satellite photography for agriculture from 1977 to mid-2025 see **Fig. 3** corroborates earlier results, with the United States, India, and PRC occupying the top three places, boasting over 1000, 800, and 500 scholars, correspondingly. Germany, Italy, and Brazil comprise the top six, with Italy occupying the 5th spot in both positions. Transitioning from the quantity of scholars to the volume of studies, Brazil falls to position 7 from position 4, but Germany ascends to position 4 from position 6.

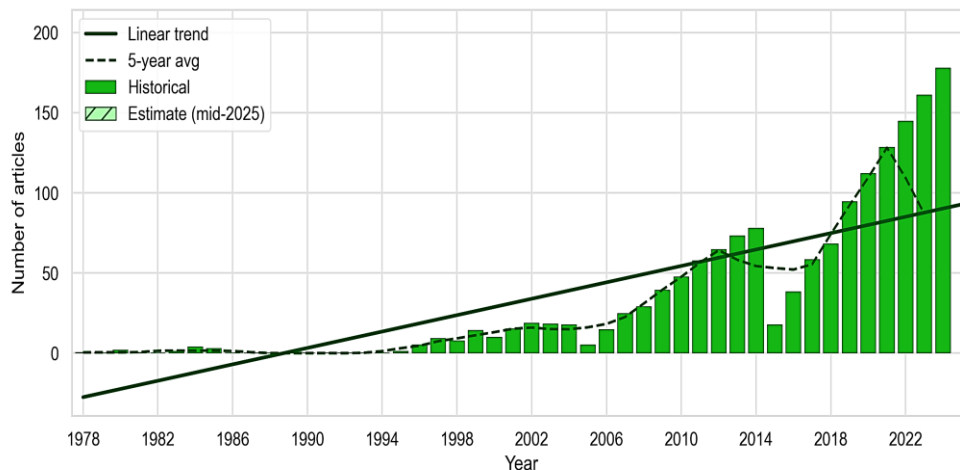


Fig 1. Annual Publishing Count (1977–Mid 2025).

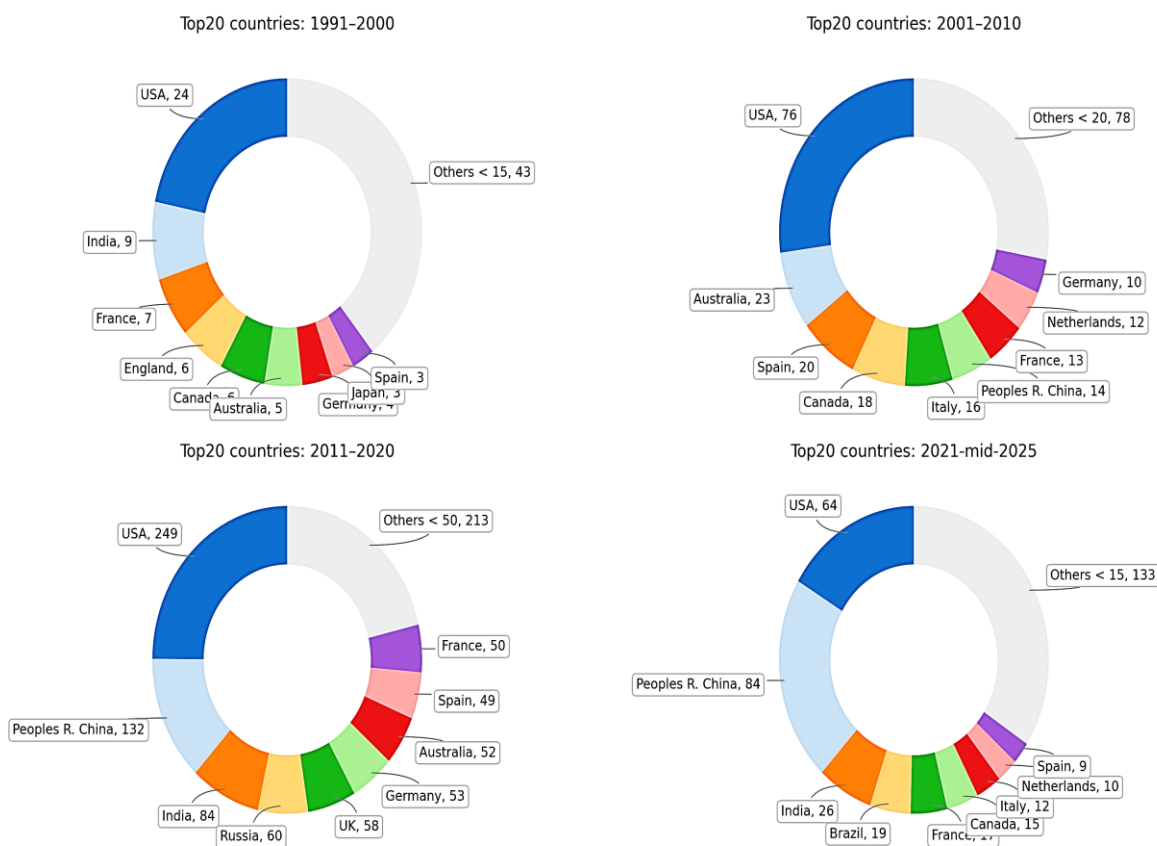


Fig 2. Leading 20 Countries by Publication Volume for the Periods (a) 1991–2000, (b) 2001–2010, (c) 2011–2020 and (d) 2021–Mid-2025.

This likely arises from the greater number of research organizations in Brazil engaged with the present issue compared to Germany, and/or the scientific articles in Brazil are often produced by a larger average number of contributors than those in Germany. During the analyzed period see **Fig. 4**, the USA consistently occupies the top two places, while the rapid ascent

of the PRC, formerly outside the top 20 from 1991 to 2000, culminates in surpassing the United States of America in 2021–2025.

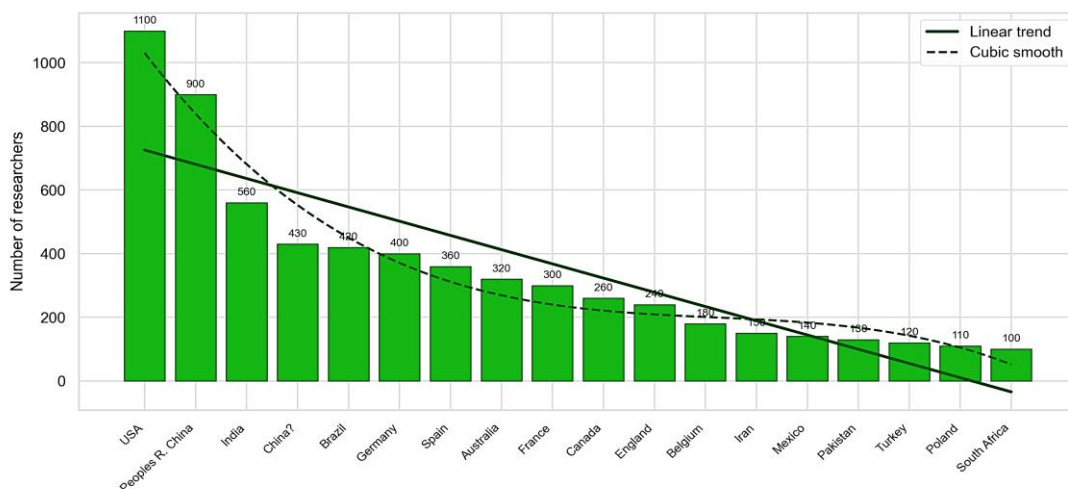


Fig 3. Leading 20 Nations by Researcher Numbers (1977–Mid-2025).

India retains a top position (rank 3 from 2021 to 2025), having surpassed a little dip over the decade 2011 to 2020 (position 5). Brazil had significant development, particularly from 2011 to 2020, whereas nations such as Germany, France, and Italy have consistently been in the top 10 list. Pakistan has lately achieved a position in the top 10 for the first time.

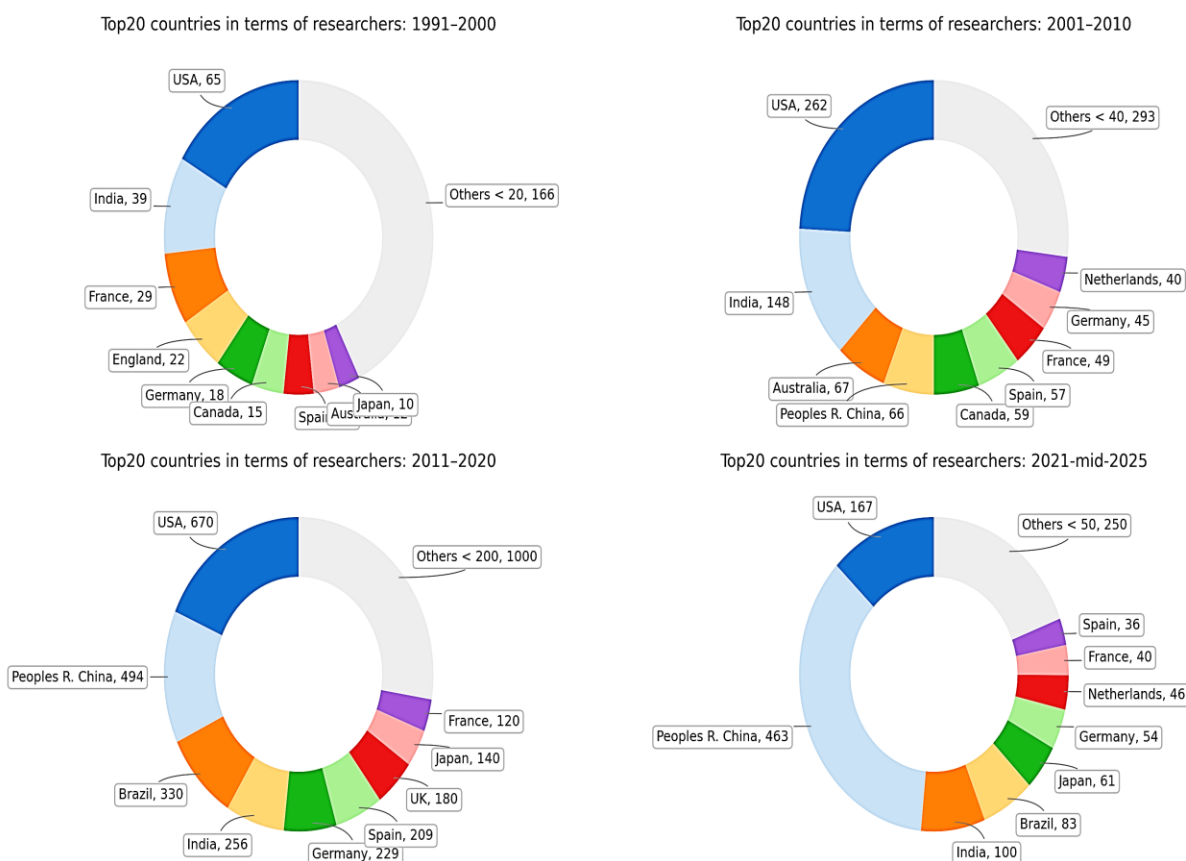


Fig 4. Leading 20 Nations by Number of Researchers Throughout the Periods 1991–2000 (a), 2001–2010 (b), 2011–2020 (c) and 2021–Mid 2025 (d).

However, the quantity of papers and researchers in each nation is not the whole narrative. The significance lies in the influence of the research generated in each nation. The quantity of citations obtained serves as a proxy for the quality of

research. This statistic is not independently reliable, since citation counts may be influenced by the institution, the researchers' place of origin, or the target audience (see [18]).

The WoS dataset is significantly constrained. Consequently, to get adequate data, emphasis was directed towards nations that published over 80 articles over the full-time frame see **Fig. 4a**, and citation distribution per publication was analyzed see **Fig. 4b**. The right side presented boxplots, a simple method for comparing various distributions. The boundaries of every box show Q1 (first) and Q3 (third) ranges of the shown distributions, whilst the orange line signifies its median. The IQR (Interquartile Range) is described as $Q3-Q1=IQR$, with the whiskers extending to 1.50 IQR from the borders of the box. We excluded the outliers from the narrative to enhance clarity. The boxplots are arranged based on the median for every distribution.

Fig. 5 illustrates that the study contributions from India and China are inferior to those of other nations, although their substantial output in publications refer to **Fig. 3** and the number of researchers refer to **Fig. 4**.

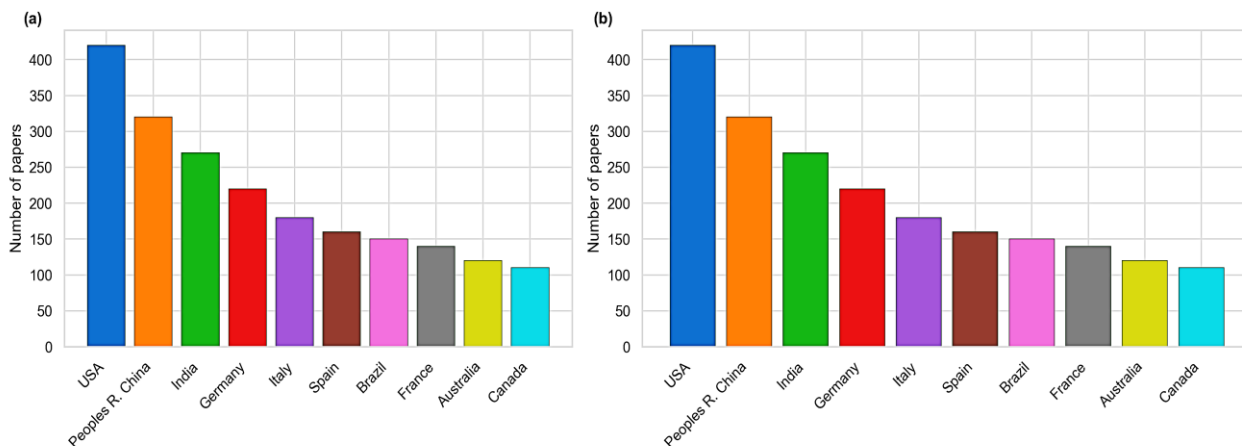


Fig 5. Research Quality: (A) Nations with Over 80 Articles (1977–Mid-2025) and (B) Distribution of Citations Per Articles.

Journal Productivity, Citation Impact and Authorship Distributions

Within the journals exhibiting the greatest volume of publications over the analyzed period (1977–mid2025), three distinctly surpass all others in terms of published articles. The CEA, IJAEOG, and IJRS have published 107, 157, and 307 articles, respectively see **Fig. 6a**. IJRS has just 1 article in the top 10 list, although three other publishers have several entries: MDPI (2, Agriculture and Agronomy), Elsevier (3, including Geoderma and those already mentioned), and Springer (2, Scientific Reports and Precision Agriculture). This image illustrates the presence of long-established scientific publishers with growing entities in the field, such as PLOS and MDPI.

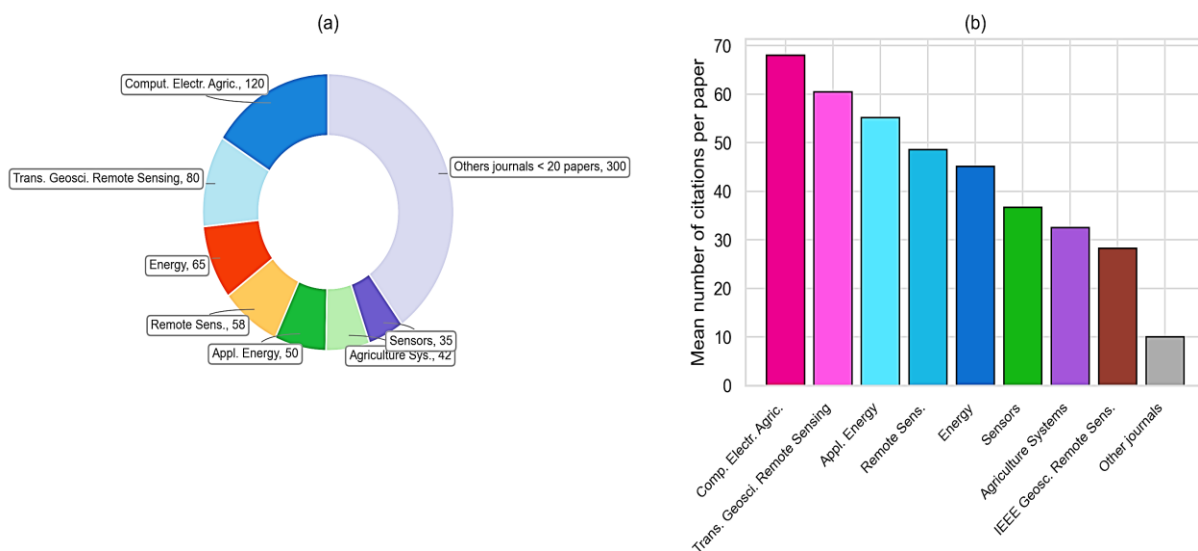


Fig 6. Journal Performance Assessed by the Quantity of Papers Produced and the Average Citations Per Publication. Panel (B) Only Shows Journals that Have Published 20 or More Articles.

To assess the impact of each publication, we analyzed the average citation frequency of the articles published within. To provide sufficient statistics, we considered just the publications most popular in the WoS see **Fig. 6b**. The data shown in the upper panel of **Fig. 6a** have undergone a partial rearrangement. Agricultural Systems ranks third, averaging 48.43 citations per paper, whereas IEEE journals (IEEE Geoscience and Remote Sensing Letters; and IEEE Transactions on Geoscience and Remote Sensing) lead the list with averages of 50.97 and 58.04 citations per publication, respectively.

The mean citation count for all other journals varies from 5 to 38. The CEA journal, despite their high publication volume, exhibit a significant decrease in average citation counts. The specialized focus of the journals on subjects such as agriculture, which is not a highly contentious global problem, and particularly agronomy, which has just recently established itself as a prominent worldwide journal (first impact factor in 2018), may be contributing causes.

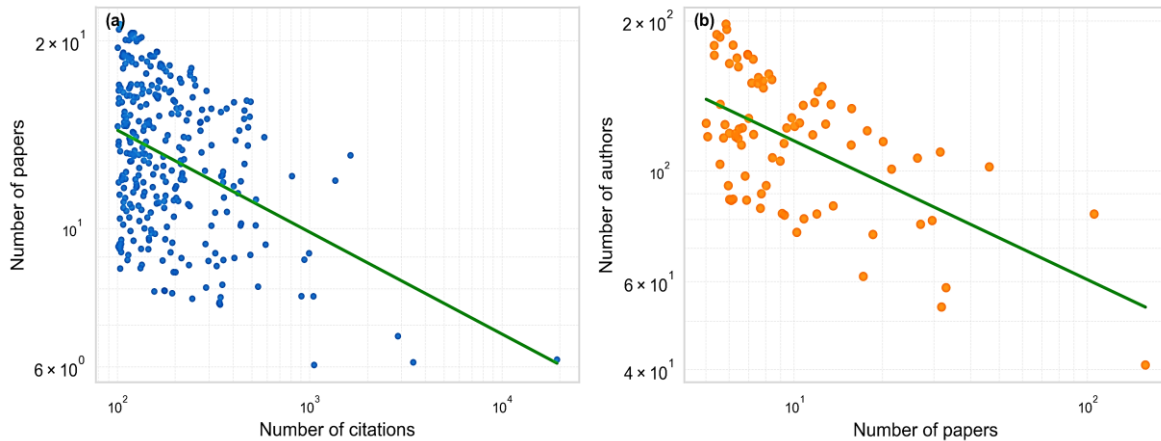


Fig 7. Distribution of (a) Citations and (b) Authorships Across the WoS Dataset (1977–Mid2025).

Fig. 7(a) illustrates the distribution of citations across all Web of Science citation indexes, while **Fig. 7(b)** depicts the distribution of publications per author. The distribution often adheres to an energy law, represented as $P(x) \sim x^{-\alpha}$. If an author's number of articles is P_t at time t , then at time $t + 1$, it is represented as $P_{t+1} = \varepsilon P_t$, where ε is a designated stimulus, suggesting that the process is multiplicative. The right panel of **Fig. 7** seems to corroborate Kauffman's notion of the “near-possible” dynamic [19]; although the original idea originated from molecular and biological evolution, it has also been used to describe the genesis of inventions.

Innovation advances incrementally along a trajectory outlined by prior contributions. The “near-possible” refers to the collection of unidentified elements that are one innovation phase away from the present level of development. As all novel entities inside the adjacent possible may be attained via the recombination of existing ones, the discovery or creation of a new item results in the updating and expansion of the adjacent possible's boundaries. The modeling of this idea was presented in [20] and is oriented on the energy-law distribution identified in many actual models; the energy-law distributions shown in **Fig. 5** corroborate the findings therein.

The primary proposition in **Fig. 7a** posits that the majority of publications earned a restricted number of citations (upper left quadrant), but a minority received a substantial number of records (lower right quadrant). Similarly, in **Fig. 7b**, a small number of scholars produced just one publication, but a select handful authored more than ten papers on the topic under investigation. The energy law indicates that the occurrence of papers obtaining n records is related to the number of publications receiving δ_n , governed by a negative δ power.

V. CONCLUSION

This bibliometric review shows research using satellite images in farming started growing greatly after 2017. The United States was still in the lead, but China quickly took over because of more research, more researchers, and publications. The United States, China, and other emerging nations had variable output and citations because of a lack of collaboration in the research, dissimilar choices of research papers, and lack of visibility of the research. The highest average citations of research were published in IEEE journals, showing their importance in distant sensing research. The variations and collaborations in research were power law in nature. In short, the study shows the research on the agricultural remote sensing satellite images undertaken around the world and the collaboration needed around the world to help more visibility in publishing, and the needed multiplex partnerships.

CRedit Author Statement

The authors confirm contribution to the paper as follows:

Conceptualization: Arulmurugan Ramu; **Methodology:** Albin Hodza; **Software:** Arulmurugan Ramu; **Data Curation:** Arulmurugan Ramu; **Writing- Original Draft Preparation:** Albin Hodza and Arulmurugan Ramu; **Visualization:** Albin Hodza; **Investigation:** Arulmurugan Ramu; **Supervision:** Arulmurugan Ramu; **Validation:** Albin Hodza and Arulmurugan Ramu

Ramu; **Writing- Reviewing and Editing:** Albin Hodza and Arulmurugan Ramu; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interests

The authors declare no conflict of interest.

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Competing Interests

There are no competing interests.

References

- [1]. J.-L. Pfund et al., "Understanding and Integrating Local Perceptions of Trees and Forests into Incentives for Sustainable Landscape Management," *Environmental Management*, vol. 48, no. 2, pp. 334–349, Jun. 2011, doi: 10.1007/s00267-011-9689-1.
- [2]. N. Heiss, J. Meier, U. Gessner, and C. Kuenzer, "A review: Potential of Earth Observation (EO) for Mapping Small-Scale agriculture and Cropping Systems in West Africa," *Land*, vol. 14, no. 1, p. 171, Jan. 2025, doi: 10.3390/land14010171.
- [3]. M. Boschetti, D. Stroppiana, P. A. Brivio, and S. Bocchi, "Multi-year monitoring of rice crop phenology through time series analysis of MODIS images," *International Journal of Remote Sensing*, vol. 30, no. 18, pp. 4643–4662, Aug. 2009, doi: 10.1080/01431160802632249.
- [4]. S. M. Samborski, N. Tremblay, and E. Fallon, "Strategies to make use of Plant Sensors-Based diagnostic information for nitrogen recommendations," *Agronomy Journal*, vol. 101, no. 4, pp. 800–816, Jul. 2009, doi: 10.2134/agronj2008.0162rx.
- [5]. T. Miller et al., "Integrating Artificial Intelligence Agents with the Internet of Things for Enhanced Environmental Monitoring: Applications in Water Quality and Climate Data," *Electronics*, vol. 14, no. 4, p. 696, Feb. 2025, doi: 10.3390/electronics14040696.
- [6]. G. P. O. Reddy, "Satellite Remote sensing Sensors: Principles and applications," in *Geotechnologies and the environment*, 2018, pp. 21–43. doi: 10.1007/978-3-319-78711-4_2.
- [7]. F. H. Goetz, "Three decades of hyperspectral remote sensing of the Earth: A personal view," *Remote Sensing of Environment*, vol. 113, pp. S5–S16, Apr. 2009, doi: 10.1016/j.rse.2007.12.014.
- [8]. R. Lottering, K. Peerbhay, and S. Adelabu, "Remote sensing applications in agricultural, earth and environmental sciences," *Applied Sciences*, vol. 15, no. 8, p. 4537, Apr. 2025, doi: 10.3390/app15084537.
- [9]. B. Hejmanowska and P. Kramarczyk, "Assessing land cover changes using the LUCAS database and Sentinel Imagery: a comparative analysis of accuracy metrics," *Applied Sciences*, vol. 15, no. 1, p. 240, Dec. 2024, doi: 10.3390/app15010240.
- [10]. F. A. F. Sham, A. El-Shafie, W. Z. W. Jaafar, A. S. M. Sherif, and A. M. A. N. Ahmed, "Advances in AI-based rainfall forecasting: a comprehensive review of past, present, and future directions with intelligent data fusion and climate change models," *Results in Engineering*, vol. 27, p. 105774, Jun. 2025, doi: 10.1016/j.rineng.2025.105774.
- [11]. K. Shukla, R. Shree, and J. Narayan, "Combining Fusion-Based thresholding and Non-Linear diffusion for improved speckle noise mitigation in SAR images," *Applied Sciences*, vol. 14, no. 19, p. 8985, Oct. 2024, doi: 10.3390/app14198985.
- [12]. Brisco, R. J. Brown, T. Hirose, H. McNairn, and K. Staenz, "Precision Agriculture and the Role of Remote Sensing: a review," *Canadian Journal of Remote Sensing*, vol. 24, no. 3, pp. 315–327, Sep. 1998, doi: 10.1080/07038992.1998.10855254.
- [13]. R. P. Sishodia, R. L. Ray, and S. K. Singh, "Applications of Remote Sensing in Precision Agriculture: a review," *Remote Sensing*, vol. 12, no. 19, p. 3136, Sep. 2020, doi: 10.3390/rs12193136.
- [14]. T. Adão et al., "Hyperspectral Imaging: A review on UAV-Based sensors, data processing and applications for agriculture and forestry," *Remote Sensing*, vol. 9, no. 11, p. 1110, Oct. 2017, doi: 10.3390/rs9111110.
- [15]. R. O.-D. Cruz, "Perceptions of higher agricultural education toward sustainable agricultural development," *Higher Education Skills and Work-based Learning*, vol. 10, no. 1, pp. 187–202, Oct. 2019, doi: 10.1108/heswbl-06-2019-0080.
- [16]. L. Zhang and L. Zhang, "Artificial Intelligence for Remote Sensing Data Analysis: A review of challenges and opportunities," *IEEE Geoscience and Remote Sensing Magazine*, vol. 10, no. 2, pp. 270–294, Apr. 2022, doi: 10.1109/mgrs.2022.3145854.
- [17]. B. Y. S. Sabas, K. G. Danmo, K. A. T. Madeleine, and B. Jan, "Cocoa Production and Forest Dynamics in Ivory Coast from 1985 to 2019," *Land*, vol. 9, no. 12, p. 524, Dec. 2020, doi: 10.3390/land9120524.
- [18]. Tahamtan and L. Bornmann, "What do citation counts measure? An updated review of studies on citations in scientific documents published between 2006 and 2018," *Scientometrics*, vol. 121, no. 3, pp. 1635–1684, Sep. 2019, doi: 10.1007/s11192-019-03243-4.
- [19]. R. Van Der Merwe, "Stuart Kauffman's metaphysics of the adjacent possible: a critique," *Interdisciplinary Science Reviews*, vol. 48, no. 1, pp. 49–61, Nov. 2022, doi: 10.1080/03080188.2022.2125614.
- [20]. A. T. Machado, C. M. A. Pinto, and A. M. Lopes, "A review on the characterization of signals and systems by power law distributions," *Signal Processing*, vol. 107, pp. 246–253, Mar. 2014, doi: 10.1016/j.sigpro.2014.03.003.

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