



REVIEW ARTICLE

A comprehensive bibliometric review of remote sensing and machine learning applications in maize yield prediction

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Abstract

Maize plays a vital role in global food security, making accurate and timely yield prediction essential for effective agricultural planning, policy formulation and resource management. In recent decades, advances in remote sensing and machine learning have transformed crop yield forecasting by enabling scalable, data-driven and high-resolution assessments that outperform conventional agronomic approaches. This bibliometric analysis provides a comprehensive assessment of global research trends, collaboration patterns and thematic evolution in remote sensing and machine learning-based maize yield prediction from 2000–2025. A total of 493 peer-reviewed articles indexed in the Scopus database were analysed using established bibliometric techniques. The results reveal a strong annual growth rate of 15.34 %, with an exponential increase in publications after 2018, reflecting rapidly growing interest in digital and AI-driven agriculture. The United States and China emerge as dominant contributors, forming a highly influential collaborative core, while countries such as India and Brazil show increasing research engagement. Remote Sensing emerges as the most productive and influential journal in this field. Thematic analysis reveals a clear shift from traditional vegetation indices toward advanced non-linear approaches, including Random Forest, deep learning models and UAV. The growing emphasis on multi-source data fusion and artificial intelligence reflects the fields' response to climate variability and the needs of precision agriculture. Overall, the integration of satellite observations with machine learning has become central to modern maize yield forecasting. Furthermore, these advancements hold strong potential to enhance sustainable farm management, climate resilience and global food security.

Keywords: AI; biblioshiny; maize; precision agriculture; scopus; yield estimation

Introduction

Maize (*Zea mays* L.) is one of the most widely cultivated and economically important cereal crops worldwide, serving as a cornerstone of global food security, livestock feed systems, industrial raw materials and biofuel production. Its extensive geographic distribution and adaptability make maize a critical contributor to the economic growth and livelihood security of many countries (1). Given its central role in agri-food systems, accurate and timely prediction of maize yield is essential for optimising crop management practices and ensuring sustainable agriculture, especially in the face of increasing climate variability, soil degradation and changing farming practices (2).

The global demand for food continues to rise in response to rapid population growth, intensifying the need for reliable crop yield prediction to support agricultural planning and food security. Yield forecasting enables efficient allocation of key inputs such as water, fertilisers and labour, thereby enhancing productivity while

minimising resource wastage (3). Accurate yield estimates are also crucial for farmers, policymakers and other stakeholders to mitigate risks associated with climate extremes, pest and disease outbreaks and market price volatility (4). At broader scales, yield predictions play a vital role in shaping food distribution systems, trade policies and strategic reserves, thereby strengthening global food security (5).

Maize yield exhibits considerable interannual variability due to fluctuations in climatic factors such as temperature and precipitation, necessitating multi-year datasets for robust agronomic characterisation of cultivars. The crop is particularly sensitive to elevated temperatures during critical phenological stages, especially flowering and grain filling, which strongly influence kernel number, grain weight and final yield quality (6). These responses are further modulated by soil fertility status, water and nutrient availability and management practices, resulting in highly

complex and nonlinear yield-determining processes (7). Such complexity poses significant challenges for accurate yield prediction. Conventional yield prediction approaches, including empirical regression models and mechanistic crop growth models, often struggle to adequately represent these complex interactions. These models typically rely on simplified assumptions and predefined functional relationships, limiting their capacity to process large, high-dimensional datasets characteristic of modern agricultural systems (8). Consequently, they frequently fail to capture the intricate interplay among climatic variables, soil properties and crop management factors that govern maize biomass accumulation and yield formation.

In recent years, machine learning (ML) techniques have emerged as powerful alternatives for crop yield prediction due to their ability to model complex, nonlinear relationships and extract meaningful patterns from large, heterogeneous datasets (9). Algorithms such as Random Forests, Gradient Boosting Machines, Support Vector Machines and Artificial Neural Networks have consistently demonstrated superior predictive performance compared to traditional approaches by integrating diverse data sources, including weather variables, soil attributes and management practices (10). Parallel to advances in ML, remote sensing technologies have revolutionised agricultural monitoring by providing spatially explicit, temporally continuous and non-destructive observations of crop growth and condition across multiple scales. Satellite- and UAV-based remote sensing data, including vegetation indices, canopy temperature and biophysical parameters, have proven highly effective for capturing crop stress, phenological dynamics and yield variability (11, 12). The integration of remote sensing with machine learning has therefore gained substantial attention as a robust framework for improving the accuracy and scalability of maize yield prediction models.

Recent bibliometric studies have evaluated remote sensing-based crop yield prediction (13–15). However, existing literature typically analysed these technologies in isolation or applied broad, multi-crop frameworks. Despite the rapid expansion of research integrating remote sensing and machine learning for maize yield prediction, the specific literature remains highly fragmented across diverse methodologies, data sources and spatiotemporal scales. To date, no study provides a dedicated, quantitative analysis combining these technologies specifically for maize over a comprehensive temporal period. Accordingly, this study presents a comprehensive bibliometric analysis to systematically map research trends, identify influential studies and thematic clusters and elucidate the evolution of these methodological approaches. This analysis provides critical insights to guide future research and support the development of more accurate, scalable and data-driven yield forecasting systems.

Methodology

Bibliometric analysis is a universally adopted approach to systematically explore research trends, thematic patterns and relationships between authors, institutions and countries, based on published scientific literature (16, 17). While various software tools such as VOSviewer, CiteSpace, SciMAT and Bibexcel exist for such quantitative inquiries, the R-based Biblioshiny interface is frequently preferred for its comprehensive functionality, intuitive design and seamless integration of analytics (18, 19). Therefore, this study utilised the interactive Biblioshiny application for

detailed performance analysis and science mapping.

Software used

The core bibliometric evaluation was executed via Biblioshiny, a web-based interface for the Bibliometrix R package (version 5.2.1), which directly parsed and managed the raw database records (20). To enhance graphical interpretation and aesthetic quality, custom visualisations were generated utilising the ggplot2 package (version 4.0.0) within the R statistical computing environment (version 4.5.1), hosted on the RStudio Integrated Development Environment (version 2024.04.01). Microsoft Excel was solely utilised as an intermediary tool to format extracted data for the custom ggplot2 visualisations. This setup ensured rigorous data handling, efficient management and reproducibility.

Data collection and screening

Among major academic repositories, the Scopus database was selected exclusively for its superior interdisciplinary coverage and subject relevance in agricultural and computational sciences. Compared to Web of Science, which exhibits high coverage overlap but narrower indexing in applied technologies, Scopus provides greater citation completeness. Additionally, extracting bulk bibliometric metadata from Google Scholar remains technically complex and Dimensions is a comparatively emerging database with evolving standards (21–23). To capture the intersection of crop science and advanced technology, a specific search string was formulated focusing on maize yield estimation via remote sensing and artificial intelligence. The exact query executed in Scopus was: TITLE (("maize" OR "corn" OR "zea mays") AND ("yield" OR "production" OR "productivity") AND TITLE-ABS-KEY ("prediction" OR "estimation" OR "forecasting" OR "model*") AND (TITLE-ABS-KEY ("Remote sensing" OR "satellite" OR "spectral" OR "UAV" OR "Drone") OR TITLE-ABS-KEY ("machine learning" OR "deep learning" OR "artificial intelligence"))) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")).

The screening process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (24) (Fig. 1). The initial search identified 654 records. Using strict inclusion and exclusion criteria to align with the study's objective, articles were filtered by publication year (2000–2025), document type (Articles only) and language (English). Although machine learning research is often shared through conference proceedings, this study limited the document type to peer-reviewed journal articles to ensure the focus remained on mature, rigorously validated methodologies rather than preliminary results. Ultimately, 493 articles were included in the final analysis and exported in CSV format on January 16, 2026. Since the search was limited to a single database (Scopus), inter-database duplicates were inherently avoided. Any intra-database duplicates, along with the standardisation of author names and the harmonisation of institutional affiliations, were automatically handled during data import using Biblioshiny's built-in disambiguation algorithms, which specifically use unique Scopus Author IDs to accurately distinguish researchers with identical names or initials.

Data analysis

The final dataset (493 articles) published between 2000 and 2025 was analysed using Biblioshiny. Key bibliometric indicators were

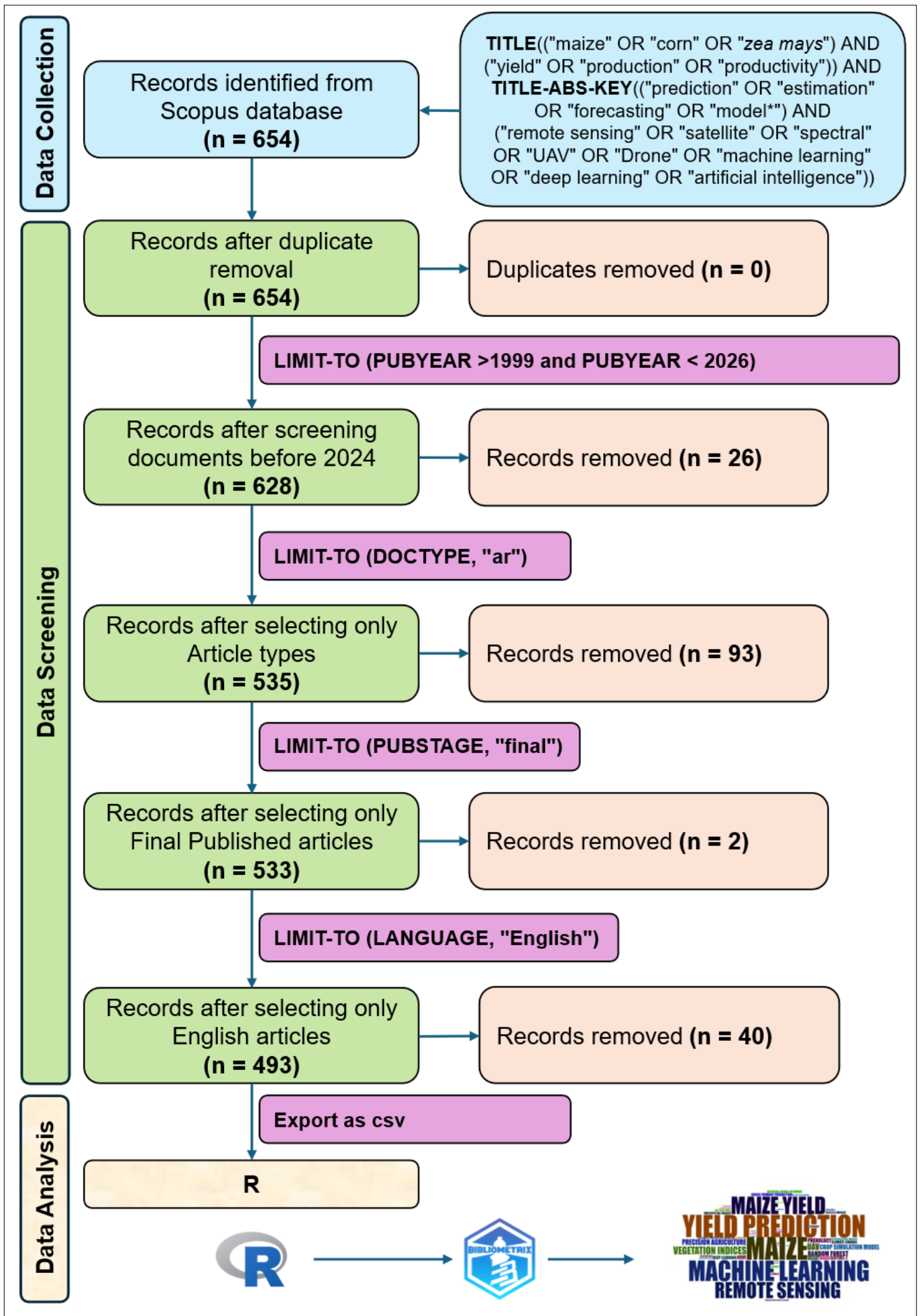


Fig. 1. PRISMA flowchart for bibliometric analysis of maize yield prediction using remote sensing and machine learning.

systematically extracted to cover various dimensions, including annual scientific production, citation impact, author dominance and international collaboration networks. The study examined trends in publication volume and geographic distribution to identify global leaders contributing to the integration of remote sensing and machine learning in maize yield forecasting.

The frequency of publications across journals was analysed using Bradford's Law by dividing journals into three equal-productivity zones. The observed distribution's fit was evaluated against the theoretical $1:n:n^2$ ratio using the mean Bradford multiplier and percentage error (25, 26). Author productivity was analysed using Lotka's law, with the exponent (n) and constant (C) calculated via the least squares method and the model's goodness-of-fit was statistically validated against the expected theoretical distribution using the Kolmogorov-Smirnov (K-S) test and R^2 values. Country-level scientific production was assessed using a full counting method, where each collaborating country receives full credit for multi-authored publications (27). Furthermore, thematic maps were generated using harmonised Author's Keywords and Biblioshiny's default Louvain clustering algorithm. Additionally, collaboration networks among authors, institutions and countries were evaluated.

Results and Discussion

Publication overview

Bibliometric analysis confirmed the growing significance of

integrating remote sensing and machine learning technologies for precise crop monitoring and yield estimation. This study covered 493 research articles published across 156 sources (journals) between 2000 and 2025 (Table 1). Research on maize yield prediction using satellite imagery and machine learning algorithms has shown rapid expansion, demonstrated by a robust annual growth rate of 15.34 %. This surge can also be substantiated by the average age of articles (5.42 years), indicating the novelty and recent acceleration of this domain. On average, each article received 39.58 citations, with 19512 total citations, corresponding to about 5.40 citations per year, highlighting the critical impact and rising academic interest in precision agriculture technologies. In addition, 1894 authors have published their research articles on maize yield prediction using these advanced tools. It is important to note that there were 5.58 co-authors per article and approximately 0.26 articles per author. The analysis appears to substantiate the collaborative nature of the scientific community, as 34.48 % of the papers involved international cooperation. The published research works were reported to have 3612 references cited, supporting the reliance on and contribution to the existing scholarly literature.

Annual scientific production and citation

Annual scientific production refers to the volume and impact of scholarly work produced within a specific year, as measured by the number of published papers and citations. Analysis from 2000 to 2025 revealed a consistent rise in research publications, with a dramatic rise observed from 2019 onwards, peaking in 2024 and

Table 1. Publication overview of research on maize yield prediction using remote sensing and machine learning

Description	Results	Description	Results
Main information about the data		Authors collaboration	
Timespan	2000:2025	Authors	1894
Sources	156	Author appearances	2751
Articles	493	Single-authored article	8
Annual growth rate %	15.34	Articles per author	0.26
Article average age	5.42	Co-authors per article	5.58
Total citations	19512	International co-authorships %	34.48
Average citations per article	39.58	Authors keywords	1279
Average citations per year per article	5.40		
Total references cited	3612		

Table 2. Annual scientific production and citation trends in maize yield prediction using remote sensing and machine learning

Year	No. of articles	Total citations	Mean total citations per article	Citable years	Mean total citations per year
2000	0	0	0	27	-
2001	0	0	0	26	-
2002	3	272	90.67	25	3.63
2003	1	7	7.00	24	0.29
2004	2	74	37.00	23	1.61
2005	4	496	124.00	22	5.64
2006	0	0	-	21	-
2007	3	159	53.00	20	2.65
2008	4	527	131.75	19	6.93
2009	4	406	101.50	18	5.64
2010	7	533	76.14	17	4.48
2011	11	882	80.18	16	5.01
2012	6	468	78.00	15	5.20
2013	5	713	142.60	14	10.19
2014	11	1370	124.55	13	9.58
2015	3	294	98.00	12	8.17
2016	13	1122	86.31	11	7.85
2017	11	550	50.00	10	5.00
2018	16	1047	65.44	9	7.27
2019	25	1527	61.08	8	7.64
2020	44	3003	68.25	7	9.75
2021	48	2559	53.31	6	8.88
2022	47	1026	21.83	5	4.37
2023	66	1358	20.58	4	5.14
2024	79	927	11.73	3	3.91
2025	80	192	2.40	2	1.20
Total	493	19512	39.58		

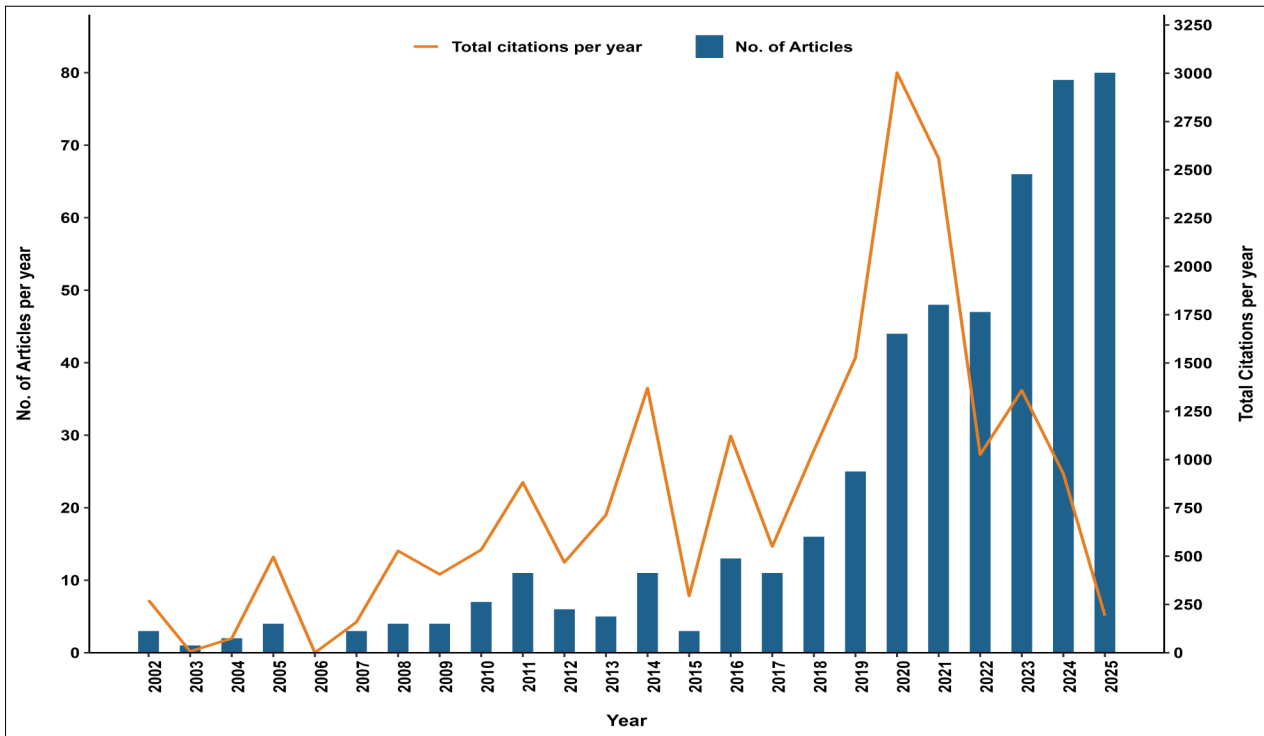


Fig. 2. Annual scientific production of articles and total citations per year related to maize yield prediction using remote sensing and machine learning.

2025 (Fig. 2). Citation trends generally paralleled publication growth, though distinct spikes in citation impact were observed around 2013 and 2020. The 2013 peak, which recorded the highest mean total citations (142.60 citations/article) and mean citations per year (10.19) (Table 2), aligns with foundational studies that successfully assimilated remotely sensed vegetation and soil moisture data into crop simulation models, alongside critical research modelling soil-water dynamics and crop yield under varying management practices (28, 29). Conversely, the highest total citation count recorded in 2020 (3003 citations) (Table 2) corresponds to a major methodological transition toward advanced artificial intelligence in precision agriculture. This period was marked by highly cited publications introducing deep learning approaches for conflating heterogeneous geospatial data, the application of machine learning ensembles for yield forecasting and the integration of UAV-based spectral indices with Random Forest algorithms (30–32). Furthermore, research in 2020 significantly advanced predictive accuracy by assessing the combined influence of soil moisture and atmospheric evaporative demand and providing comparative assessments of environmental variables and machine learning algorithms at regional scales (33, 34). There was a pronounced exponential increase in publication volume from 2019 to 2025, reflecting the rapid adoption and increasing relevance of remote sensing and machine learning algorithms in maize yield prediction. In 2025, the

number of publications reached its peak with 80 articles, closely followed by 79 articles in 2024 and 66 in 2023. These recent peaks substantiate the rapid advancements in computational power, the open availability of high-resolution satellite data and the heightened global focus on precision agriculture and AI-driven sustainability.

Publication and impact metrics analysis of the top 10 journals

The analysis of journal performance revealed substantial variations in impact and citation metrics across these publishing venues (Table 3). A total of 156 sources have contributed to research works related to maize yield prediction using remote sensing and machine learning. Remote Sensing emerged as the indisputable leading journal with an H-index of 27, a G-index of 46 and 2216 citations across 60 published papers, demonstrating its sustained and significant academic influence. Computers and Electronics in Agriculture followed with an H-index of 19, a G-index of 32 and 1717 citations, further reflecting its pivotal role in the intersection of agriculture and technology. Notably, Remote Sensing of Environment (H-index: 15, G-index: 15) recorded the highest total citation count (2690) despite having fewer published articles (15), indicating an exceptionally high impact per paper. Agricultural and Forest Meteorology (H-index: 13, G-index: 18) also evinced strong scholarly influence with 1132 citations, highlighting

Table 3. Publication and impact metrics of the top 10 journals

Source	H index	G index	M index	TC	NP	PY start
Remote sensing	27	46	1.929	2216	60	2013
Computers and electronics in agriculture	19	32	0.864	1717	32	2005
Remote sensing of environment	15	15	0.882	2690	15	2010
Agricultural and forest meteorology	13	18	0.591	1132	18	2005
Agronomy	11	16	1.375	265	18	2019
Field crops research	11	17	0.733	615	17	2012
Agricultural water management	10	18	0.667	597	18	2012
International journal of applied earth observation and geoinformation	9	10	0.6	566	10	2012
Agriculture (Switzerland)	8	14	1	411	14	2019
Precision agriculture	8	10	0.4	349	10	2007

*TC - Total Citations; NP- Number of articles; PY start- Publication year started from.

its steady contribution to the field. Agronomy (H-index: 11, G-index: 16) demonstrated rapid recent growth, as evidenced by a high M-index of 1.375, indicating strong potential for future impacts in yield prediction research. Additionally, journals such as the International Journal of Applied Earth Observation and Geoinformation and Agriculture showed lower H-indices (9 and 8) and fewer total citations (566 and 411, respectively), yet they continue to provide valuable specialised contributions. This dataset highlights the varying levels of impact within the field, ranging from high-volume, high-impact leaders to specialised sources focusing on specific technological applications.

Journal contributions based on Bradford's law

Bradford's Law was applied to identify the core journals contributing to maize yield prediction utilising remote sensing and machine learning. This law categorised the identified 156 journals into three distinct zones based on their scholarly output (Table 4). Zone 1 consisted of 6 journals with 163 articles (33.06%). The top six journals viz. Remote Sensing, Computers and Electronics in Agriculture, Agricultural and Forest Meteorology, Agricultural Water Management, Agronomy and Field Crops Research, were pivotal to the field, making substantial contributions to the body of research (Fig. 3). Zone 2 with 20 journals contributed 170 articles (34.48% of the total publications), while Zone 3 consisted of 130 journals with 160 articles (32.45%). Although Zone 3 journals are numerous, they each contributed fewer articles, representing more peripheral or highly specialised sources within the field.

To test the applicability of Bradford's distribution, the mean Bradford multiplier (n) was calculated as 4.917, derived from the individual zone transition multipliers of 3.333 and 6.500. Applying the theoretical $1:n:n^2$ relationship, the expected number of journals across the three zones was projected as 6, 29.50 and 145.04, respectively. This resulted in a total expected count of 180.54 journals with a percentage error of 15.73% when compared to the observed 156 journals. This deviation from the ideal Bradford ratio suggests that in a highly interdisciplinary domain like ML-based yield estimation, the literature is scattered more broadly and the core journal concentration is more diffuse than in traditional, narrower disciplines. This distribution demonstrated how a small group of core journals (Zone 1) could significantly shape the direction of research in ML-based yield estimation, whereas other journals in Zones 2 and 3 contributed to

a broader, yet less concentrated, impact. Using Bradford's Law, researchers can focus on the most influential journals, providing a roadmap for future academic exploration.

Journal publication trends over time on maize yield prediction using remote sensing and machine learning

The production trends of the top five journals related to Maize yield prediction using remote sensing and machine learning over time revealed a steady increase in article output across all journals (Fig. 4). Remote Sensing started with no publications related to maize yield prediction using this technology from 2002 to 2012 and has shown exponential growth, reaching 60 articles by 2025. This increase reflects the growing importance of satellite-based monitoring and spectral analysis in agricultural research, particularly where high-resolution imagery plays a critical role in crop yield prediction. Computers and Electronics in Agriculture also demonstrated a consistent growth, starting with 1 article in 2005 and reaching 32 by 2025, signifying the role of integrating advanced computational algorithms and sensor technologies for precision farming. Agricultural and Forest Meteorology initiated publishing research related to this domain in 2005 and increased its output from 1 article to 18 by 2025, reflecting the continued academic interest in agrometeorology and its integration with predictive models for yield forecasting. Similarly, Agricultural Water Management and Agronomy demonstrated upward trends in publications, with Agricultural Water Management growing from 1 article in 2012 to 18 in 2025 and Agronomy showing rapid adoption to reach 18 articles by 2025. These journals, particularly when linked with machine learning, focus on crop productivity, resource optimisation and environmental factors, all crucial for improving maize yields. The growing publication output across these journals confirmed the increasing academic focus on agricultural sciences, with artificial intelligence serving as a critical tool for improving crop yield predictions and sustainability in agricultural practices. This overall growth underscored the growing importance of these journals in advancing agricultural research, particularly in addressing global challenges related to maize production and the optimisation of agricultural practices through advanced technological interventions.

Publication and impact metrics of the top 10 authors

Table 5 presents the publication and impact metrics of the top 10 authors who have published in Maize yield prediction using

Table 4. Journal contribution zones based on Bradford's law

Zone	No. of journals (observed)	No. of journals (expected*)	No. of documents	Percentage
Zone 1	6	6.00	163	33.06
Zone 2	20	29.50	170	34.48
Zone 3	130	145.04	160	32.45
Total	156	180.54	493	100.00

*Expected journals calculated based on $1:n:n^2$ with mean multiplier ($n = 4.917$).

Table 5. Publication and impact metrics of the top 10 authors

Author	Articles	H index	G index	M index	Total citations	PY start
Zhang Z	13	10	13	0.667	741	2012
Li Y	14	9	14	0.600	503	2012
Zhang X	14	9	14	1.286	335	2020
Anderson M	9	8	9	0.444	685	2009
Archontoulis SV	8	7	8	0.636	958	2016
Chen S	9	7	9	1.167	113	2021
Guan K	7	7	7	0.778	528	2018
Hoogenboom G	7	7	7	0.368	626	2008
Li X	9	7	9	0.500	191	2013
Lobell DB	7	7	7	0.538	761	2014

PY start- Publication year started from.

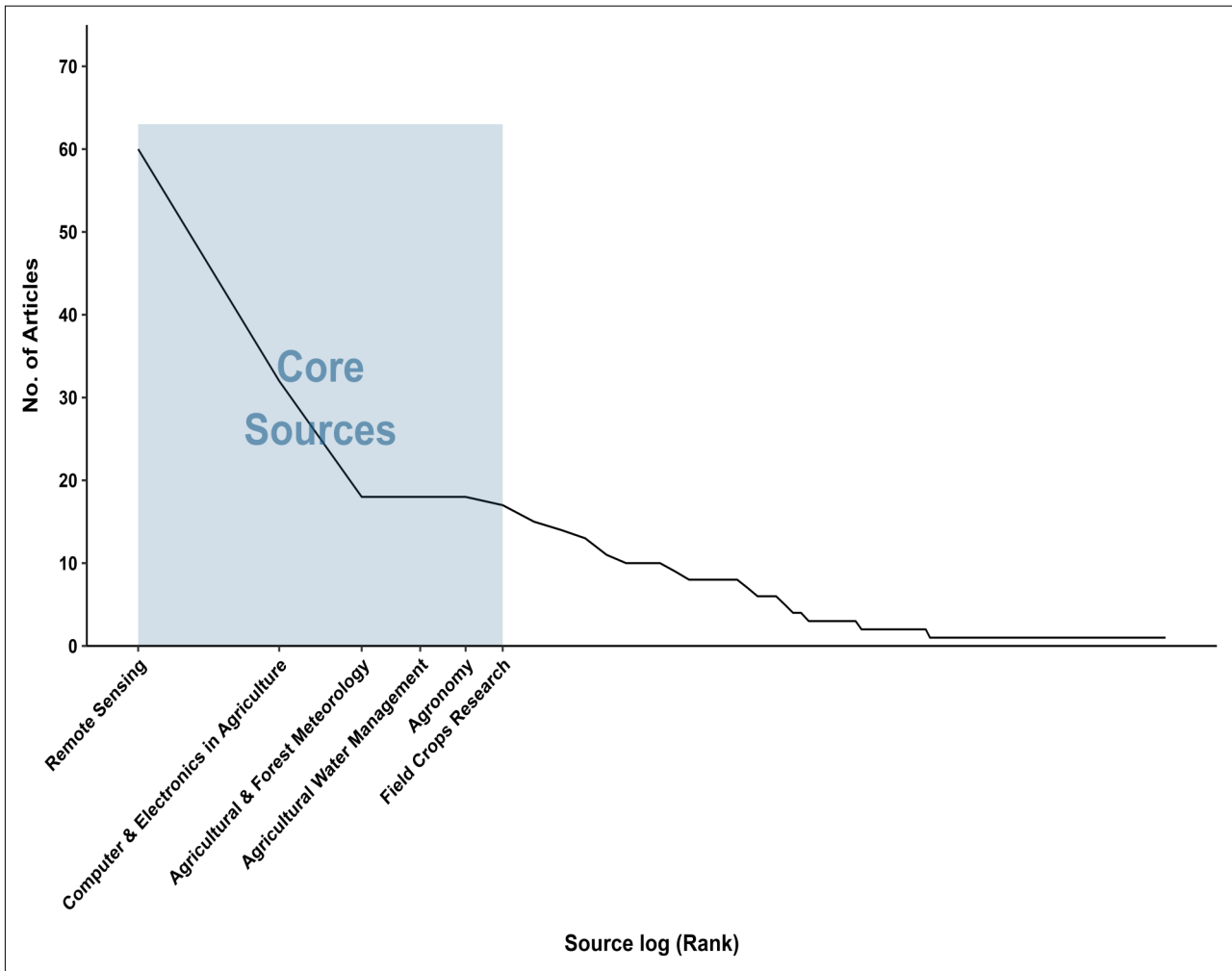


Fig. 3. Core sources identified by Bradford's law for maize yield prediction research.

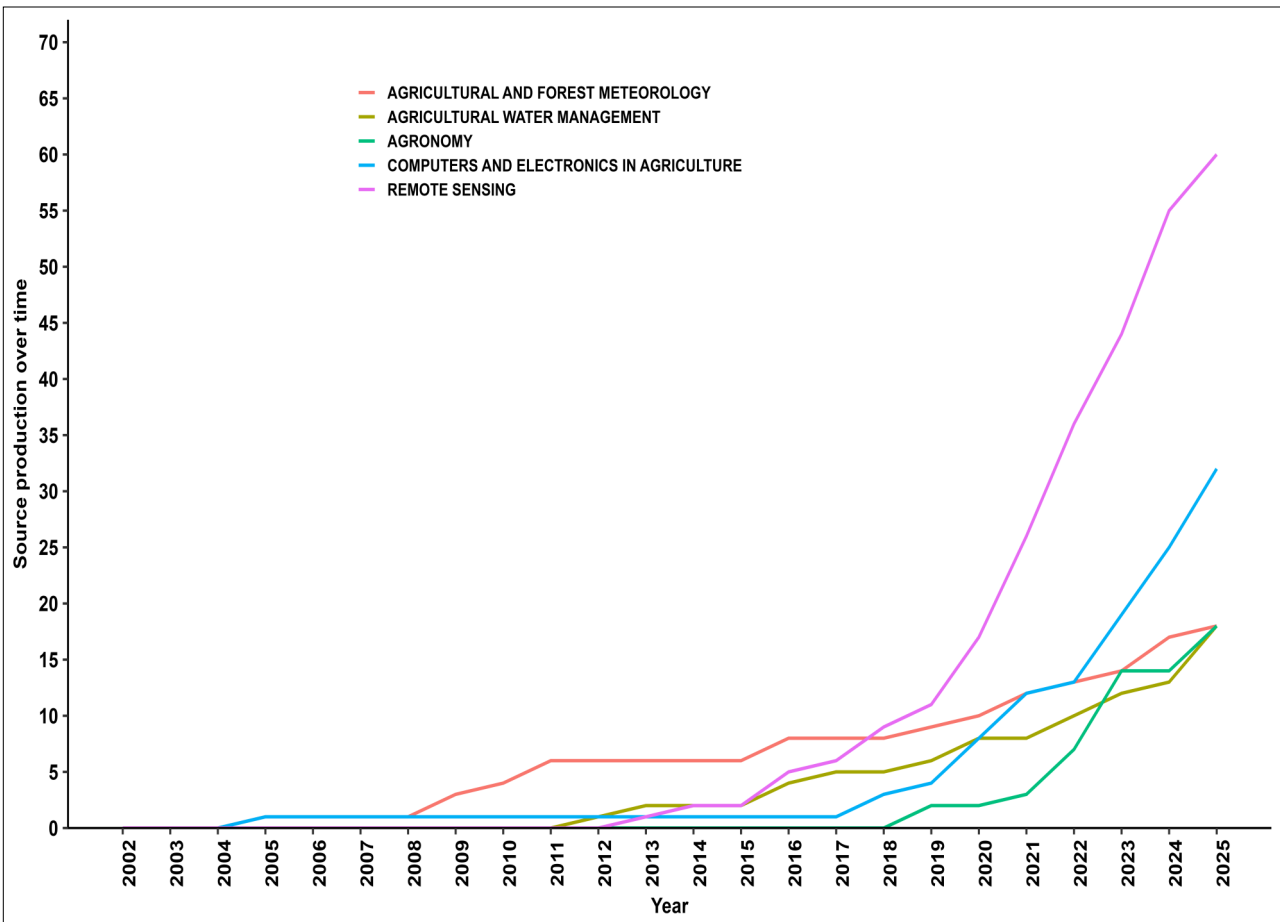


Fig. 4. Journal publication trends over time.

remote sensing and machine learning. Zhang Z appears as a leading author, with 13 articles, an H-index of 10 and 741 citations, reflecting his significant influence in the field. Li Y and Zhang X follow with the highest number of articles (14 each), with Li Y recording an H-index of 9 and 503 citations. Zhang X evinced a rapid recent growth, demonstrated by a high M-index of 1.286, despite a moderate citation count of 335. Archontoulis SV recorded the highest total citations (958) from only 8 articles, while Lobell DB achieved 761 citations from 7 papers. Anderson M (9 articles, H-index: 8) and Hoogenboom G (7 articles, H-index: 7) maintained significant scholarly influence with 685 and 626 citations, respectively. Chen S (9 articles) demonstrated emerging potential with a high M-index of 1.167. Overall, these authors demonstrated varying levels of contribution, with Zhang Z leading in H-index and Archontoulis SV dominating citation metrics, underscoring the critical role of these researchers in advancing AI and satellite-based maize yield prediction.

Author productivity through Lotka's law

Lotka's law posits that a limited proportion of authors are responsible for many publications, whereas most authors produce only a small number of publications (23, 35). The findings confirmed that a significant portion of authors (77.3 %) contributed only one document, reflecting the "long tail" distribution where many authors were less productive. Also, fewer authors made more substantial contributions, with 13.1 % contributing two documents, 5.1 % contributing three documents and even fewer authors contributing more, such as two authors producing 14 documents each. Lotka's distribution was mathematically quantified and statistically validated. Using the least squares method, the specific exponent parameter (n) for this dataset was calculated as 2.7971, with a constant (C) of 0.8051. The regression line demonstrated a strong overall correlation ($R^2 = 0.9608$), visually supporting the general inverse-square pattern depicted by the dashed theoretical line in Fig. 5. However, a Kolmogorov-Smirnov (K-S) goodness-of-fit test indicates the data does not strictly conform to Lotka's idealised distribution, as the maximum deviation (0.03165) slightly exceeds the critical value

(0.03125 for $p = 0.05$, $n = 1,894$). Despite exhibiting a highly skewed distribution, author productivity in this domain deviates marginally from Lotka's exact theoretical model (Table 6).

Authors' production over time

Fig. 6a offers a clear overview of the evolution of authors' productivity and citation impact, highlighting major contributors and trends in maize yield prediction research using remote sensing and machine learning. The size of each bubble corresponds to the number of articles published by an author per year, with larger bubbles reflecting greater research output. Authors like Anderson M and Li Y demonstrated consistent research publication output over extended periods, revealing their sustained engagement in the field since 2009 and 2012, respectively. The colour intensity of each bubble reflects citation counts, with darker shades indicating higher impact. For example, Zhang Z's work in 2021 recorded substantial citations (396 citations), driven primarily by highly cited research integrating satellite-derived climatic indices to predict smallholder maize yield using deep learning and Bayesian neural network approaches (36, 37). Similarly, Wang S's contributions in 2020 achieved 326 citations, primarily associated with a widely cited deep learning approach for conflating heterogeneous geospatial data and the application of modified vegetation indices via UAVs (30, 38).

The horizontal lines depict each authors' research timeline, where longer lines indicate sustained contributions, such as Anderson M, whose work extends over more than 15 years. In contrast, authors like Zhang X and Chen S show shorter, highly concentrated timelines starting around 2020. The bubble distribution also reveals differences in publication patterns. Some authors, such as Wang Y, recorded a sharp rise in productivity with six publications in 2025, whereas others, like Li Y, maintained a steady output initially before substantially accelerating their publication rate in recent years.

Most relevant institutions and publication trends over time

Table 7 presents the top 10 institutions contributing to research on maize yield prediction using remote sensing and machine

Table 6. Author productivity through Lotka's law

Documents written	No. of authors	Per cent of authors
1	1465	77.3
2	249	13.1
3	97	5.1
4	29	1.5
5	18	1
6	8	0.4
7	10	0.5
8	7	0.4
9	6	0.3
10	1	0.1
12	1	0.1
13	1	0.1
14	2	0.1

Table 7. Top 10 most relevant institutions

Institution	Country	Articles
University of Illinois Urbana-Champaign	USA	29
China Agricultural University	China	25
University of Wisconsin-Madison	USA	23
University of Chinese Academy of Sciences	China	22
Beijing Normal University	China	21
Northwest A&F University	China	21
Institute of Geographic Sciences and Natural Resources Research	China	18
University of Nebraska-Lincoln	USA	18
Michigan State University	USA	16
Cornell University	USA	14

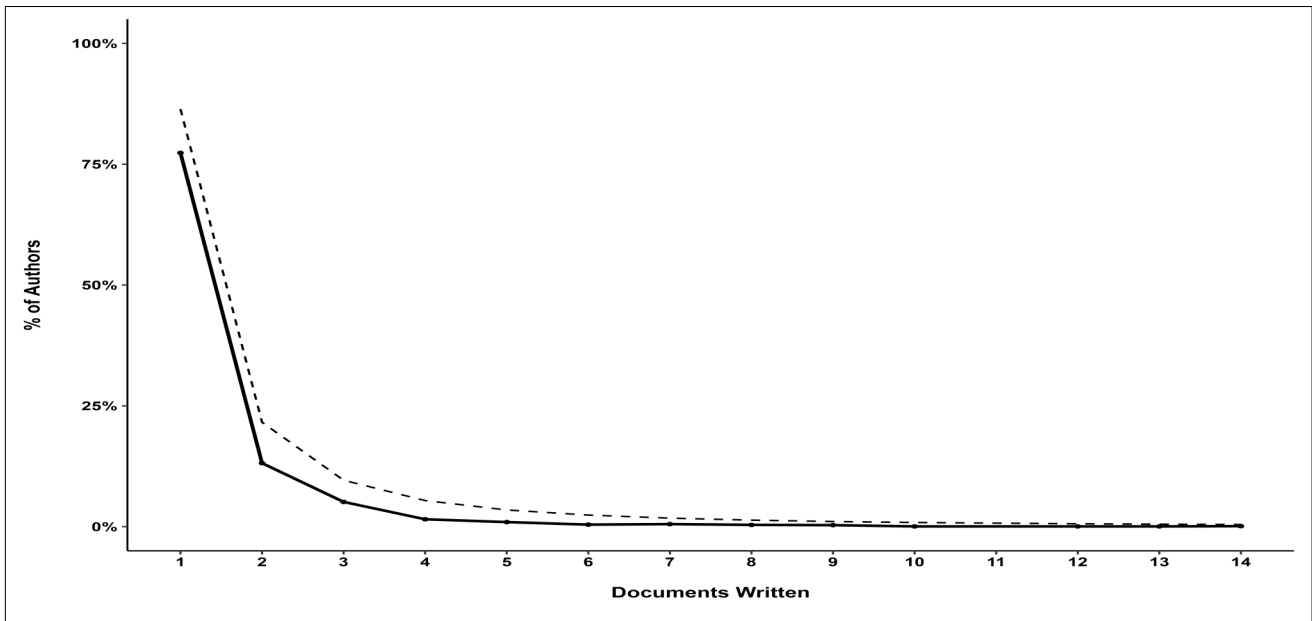


Fig. 5. Author productivity analysis based on Lotka's law.

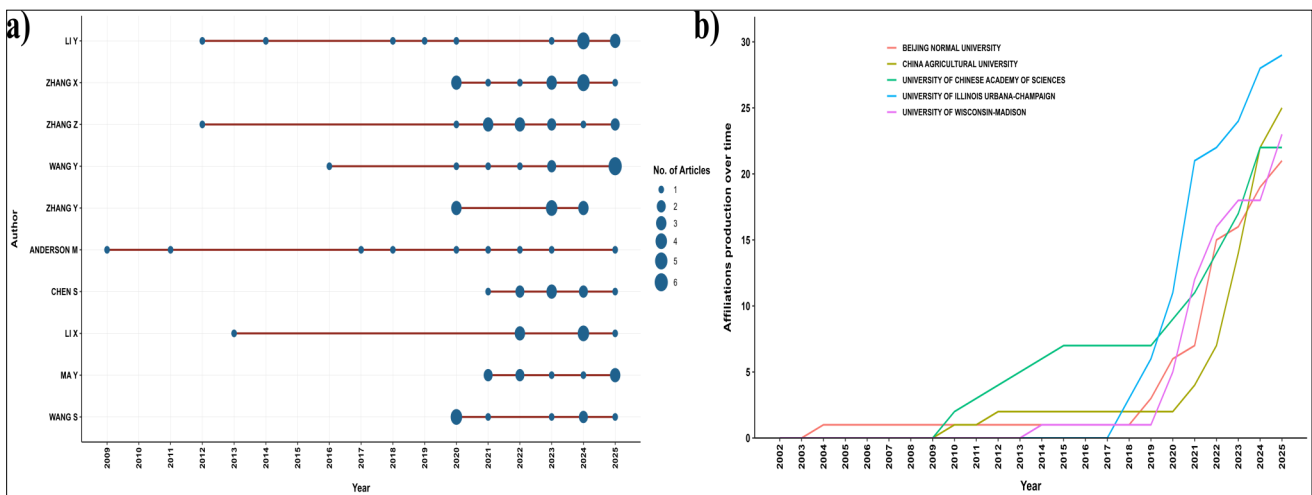


Fig. 6. Authors and affiliations production over time: a. Authors' production over time, b. Affiliations production over time.

learning. Institutional publication counts were calculated using a full counting method, where each affiliated institution receives one full credit for a co-authored article. The University of Illinois Urbana-Champaign, USA, ranks first with 29 publications, highlighting its strong role in combining advanced computational approaches with agricultural research, followed closely by China Agricultural University, China, with 25 articles. Both institutions play a key role in advancing the application of AI in crop science. The University of Wisconsin-Madison, USA (23 articles) and the University of the Chinese Academy of Sciences, China (22 articles) also make substantial contributions, reflecting their focus on satellite-based data analysis. Beijing Normal University, China and Northwest A&F University, China, each with 21 publications, further illustrate China's growing prominence in this research area. The Institute of Geographic Sciences and Natural Resources Research, China and the University of Nebraska-Lincoln, USA (18 articles each), emphasise the global expansion of precision agriculture research. Michigan State University, USA (16 articles) and Cornell University, USA (14 articles) continue to provide influential contributions from leading U.S. agricultural research institutions. It should be noted that these metrics represent absolute productivity and are not normalised for institution size, faculty count, or research funding, which naturally advantages larger research universities. Furthermore, the top 10 most productive institutions are

exclusively located in just 2 countries, comprising 5 institutions from the United States and 5 from China.

Fig. 6b illustrates the publication trends of key institutions in maize yield prediction research using remote sensing and machine learning over time. The University of Illinois Urbana-Champaign demonstrated the most dramatic growth; after having a negligible output before 2018, it experienced a rapid increase, reaching 29 articles by 2025. This steep trajectory aligns with the global boom in AI applications in agriculture. China Agricultural University showed a similar pattern of rapid acceleration, starting with minimal activity before 2020 and surging to 25 articles by 2025. The University of Chinese Academy of Sciences displayed a steadier, early engagement, growing consistently from 2010 before accelerating alongside the others in recent years. Beijing Normal University showed limited publication activity until 2019, followed by a rapid increase that reached 21 articles by 2025. A similar pattern is evident at the University of Wisconsin-Madison, where a marked rise in research output has been observed since 2020. These patterns highlight the dynamic evolution of agricultural research, with leading institutions substantially expanding their efforts in remote sensing and machine learning over the past 5 years.

Countries' scientific production and publication trends over time

The global contribution to maize yield prediction research using remote sensing and machine learning reflects a concentrated yet expanding interest across various regions (Fig. 7a). To accurately reflect the collaborative weight of each nation, scientific production was evaluated using a full counting method based on all author affiliations, meaning a single article contributes multiple times to a country's total if co-authored by several researchers from that nation. Consequently, the USA leads the field with 538 occurrences, as shown in Table 8, demonstrating sustained leadership and early adoption of precision agricultural technologies. China, with 452 occurrences, follows closely, reflecting its massive investment in agricultural modernisation and artificial intelligence, particularly accelerating after 2015. Notably, a distinct duopoly exists in this domain, as the output from these two nations far exceeds that of others. India has emerged as a key player in the developing world, increasing its output from negligible numbers in the early years to 55 occurrences by 2025, highlighting the country's growing focus on digital agriculture. France (52 occurrences) and Brazil (51 occurrences) have also made considerable contributions, with Brazil's research underscoring the importance of maize production in South American economies. Other countries like Germany (46 occurrences), Canada (34 occurrences) and Iran (25 occurrences) have made significant contributions, enhancing global knowledge on yield prediction models.

Fig. 7b presents the publication trends from 2002 to 2025, revealing a dramatic surge in output. The USA exhibited a consistent upward trajectory, growing from eight in 2002 to 538 occurrences in 2025, with a sharp acceleration observed post-2018. China experienced an explosive exponential growth pattern; while it had only 10 occurrences in 2010, its output skyrocketed to 452 by 2025, nearly closing the gap with the USA. India, France and Brazil showed a different pattern, characterised by latent interest followed by rapid recent emergence; for instance, India's production jumped from near zero before 2017 to 55 occurrences by 2025. These trends reflect a global shift where advanced computational tools are increasingly being democratised and adopted beyond the traditional research hubs of the West.

Collaborative pattern of the corresponding authors' countries

The global landscape of maize yield prediction research using remote sensing and machine learning is dominated by the United States, which contributed 148 publications (30 %). Its output is largely driven by single-country publications (SCPs), accounting for 105 articles, while multiple-country publications (MCPs) comprise 43 articles, indicating relatively limited international collaboration. China ranks a close second with 136 articles (27.6%) and demonstrates a stronger collaborative orientation, with MCPs representing 33.1 % of its output, reflecting its increasing integration

into international research networks. Brazil (16 articles) and France (14 articles) occupy intermediate positions, exhibiting moderate levels of international collaboration with MCP shares of 31.3 % and 28.6 %, respectively. India (12 articles), in contrast, shows a pronounced domestic focus, with 11 SCPs and only one MCP (8.3 %), highlighting substantially lower international engagement compared to leading contributors such as the USA and China. Germany presents a more balanced collaboration pattern, with half of its publications produced through international partnerships. Even more strikingly, the United Kingdom, Pakistan, Nigeria and Japan record 100 % MCP rates, indicating that their contributions to this research area are entirely reliant on global collaborations. Similarly, South Africa (60 % MCP) and Mexico (57.1 % MCP) demonstrate strong cross-border research engagement, underscoring the growing importance of international cooperation in advancing maize yield forecasting research worldwide (Fig. 7c).

Citation profile of top countries

Table 9 reveals the citation profiles of the top countries in maize yield prediction research via remote sensing and machine learning, ranked according to the total global citations their affiliated publications have accumulated from the time of publication up to the date of data retrieval. The USA dominates with 7894 total citations and an average of 53.30 per article, highlighting its lasting academic prominence. China ranks second at 3880 citations and 28.50 per article, yet the lower average points to a priority on output quantity rather than individual paper impact. Canada distinguishes itself by recording the highest average impact, with 97.80 citations per article, despite a relatively modest total citation count of 880. This indicates that, although its publication volume is limited, Canadian research in this area exerts a disproportionately strong influence, likely driven by highly specialised or niche expertise. Spain (68.20 average) and Italy (60.80) also shine among European contributors, while Mexico (57.40) and France (49.90) exhibit strong per-article impact from focused work. Brazil (32.60) and Iran (30.20) offer steady, moderate contributions. Overall, the USA dominates in volume and totals, but nations like Canada and Spain prove that high impact stems from quality over quantity.

Global citation analysis of top papers related to maize yield estimation

The top 10 most globally cited papers on maize yield prediction have shifted significantly from traditional crop simulation (e.g., DSSAT standalone studies) toward the integration of Remote Sensing and Machine Learning technologies (Table 10). Johnson's publication in Remote Sensing of Environment leads in total citations (387 citations) and sets a benchmark for regional-scale yield forecasting using pre-season and in-season satellite observations (39). The study is particularly influential because it demonstrated that remotely sensed indicators such as the normalised difference vegetation index (NDVI) and land surface temperature (LST) can effectively substitute for, or complement, conventional ground-based agronomic data in crop yield prediction. Following closely is Ines et al. (Remote Sensing of Environment) with 362 citations, which remains a cornerstone study for assimilating satellite data into crop growth models to correct simulation errors and enhance spatial scalability (28).

A notable emergence in the field is Shahhosseini et al. (Scientific Reports), which, despite its recent publication, has

Table 8. Top 10 most relevant countries

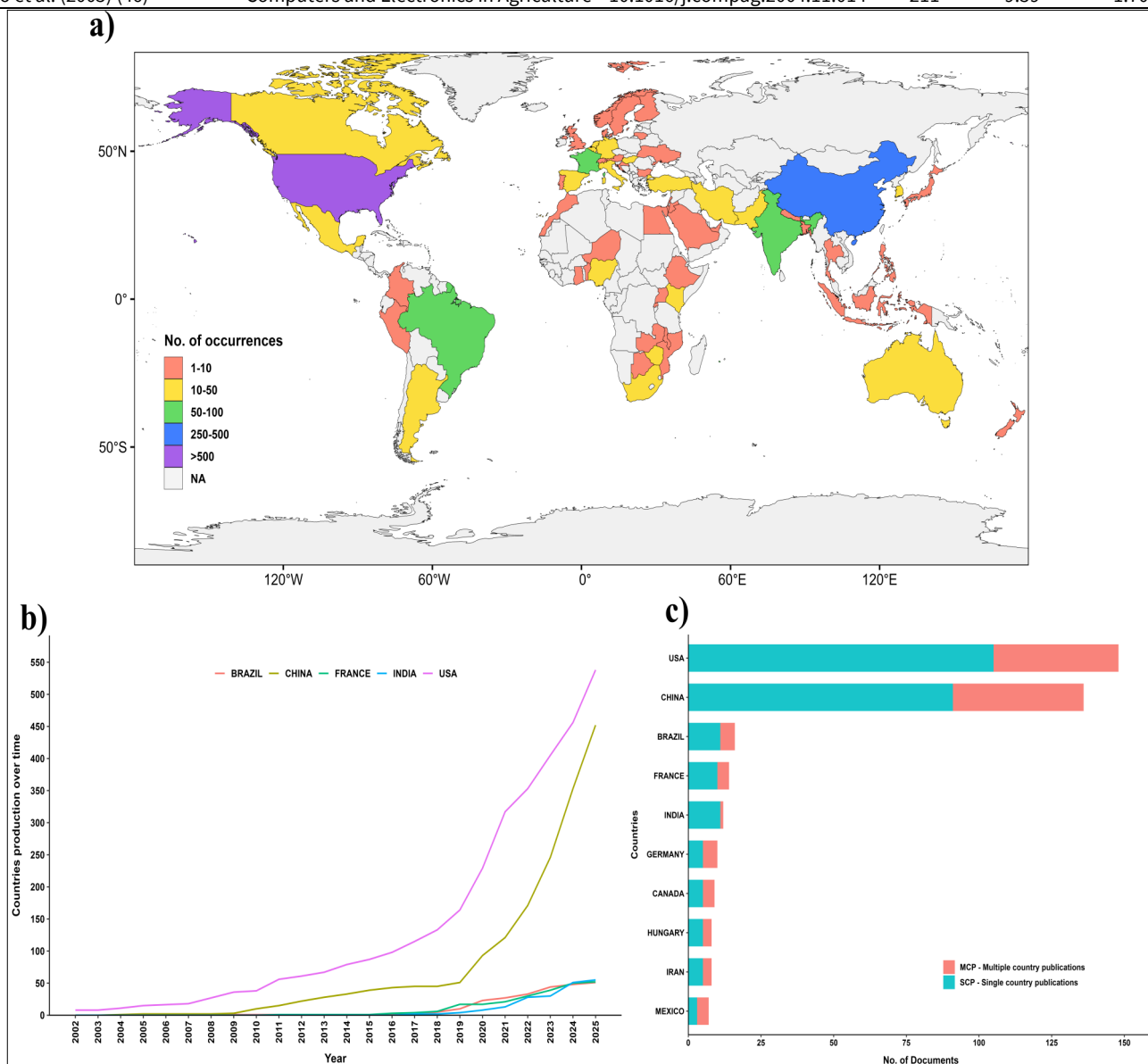
Country	Occurrences
USA	538
China	452
India	55
France	52
Brazil	51
Germany	46
Canada	34
Iran	25
Australia	23
South Africa	23

Table 9. Citation profile of top countries

Country	Total citations	Average article citations
USA	7894	53.30
China	3880	28.50
Canada	880	97.80
France	699	49.90
Brazil	521	32.60
Mexico	402	57.40
Spain	341	68.20
Italy	243	60.80
Iran	242	30.20
Germany	232	23.20

Table 10. Citation profile of key documents on maize yield prediction

Paper	Journal	DOI	Total citations	Citations per year	Normalised total citations
Johnson (2013) (39)	Remote Sensing of Environment	10.1016/j.rse.2013.10.027	387	29.77	3.11
Ines et al. (2013) (28)	Remote Sensing of Environment	10.1016/j.rse.2013.07.018	362	25.86	2.54
Shahhosseini et al. (2021) (40)	Scientific Reports	10.1038/s41598-020-80820-1	334	55.67	6.26
Jin et al. (2019) (41)	Remote Sensing of Environment	10.1016/j.rse.2019.04.016	329	41.13	5.39
Geipel et al. (2014) (44)	Remote Sensing	10.3390/rs61110335	297	22.85	2.38
Khanal et al. (2018) (42)	Computers and Electronics in Agriculture	10.1016/j.compag.2018.07.016	285	31.67	4.36
Battude et al. (2016) (45)	Remote Sensing of Environment	10.1016/j.rse.2016.07.030	272	24.73	3.15
Ramos et al. (2020) (32)	Computers and Electronics in Agriculture	10.1016/j.compag.2020.105791	230	32.86	3.37
Ma et al. (2021) (37)	Remote Sensing of Environment	10.1016/j.rse.2021.112408	218	36.33	4.09
Uno et al. (2005) (46)	Computers and Electronics in Agriculture	10.1016/j.compag.2004.11.014	211	9.59	1.70

**Fig. 7.** Global scientific production and collaboration patterns [Generated by using Biblioshiny (Bibliometrix package, R software), default map options]: a. Country scientific production map; b. Countries' production over time; c. Collaborative pattern of the corresponding authors' countries.

accrued 334 citations with an exceptional annual citation rate of 55.67 (40). This highlights the explosive academic interest in ensemble machine learning models and their ability to outperform traditional regression or simulation approaches in yield forecasting. Similarly, Jin et al. (Remote Sensing of Environment) obtained 329 citations, emphasising the fusion of optical and radar data for smallholder yield mapping, a critical advancement for data-scarce regions (41). Other key works, such as Ramos et al. and Khanal et al. in *Computers and Electronics in Agriculture*, focus on the computational aspects of precision agriculture, demonstrating the efficacy of algorithms like Random Forest and Deep Learning in processing high-resolution UAV and satellite imagery (32, 42). Collectively, these highly cited documents reflect a paradigm shift in maize yield prediction from purely mechanistic models to data-driven, interdisciplinary approaches that leverage the synergy of satellite observation and artificial intelligence to address global food security challenges.

Reference publication year spectroscopy (RPYS)

Reference publication year spectroscopy (RPYS) is an analytical method employed to identify the historical origins and major discoveries within research fields, offering a timeline of significant developments (22, 43). The analysis of the cited references over time, as depicted in Fig. 8, reveals distinct evolutionary trends in maize yield prediction research using remote sensing and machine learning, aligning with the exponential growth of the field. The blue line in the figure represents the number of cited references per year, showing a relatively flat baseline until the late 1990s, followed by a sharp, consistent ascent starting around 2000. This initial rise coincides with the early adoption of precision agriculture and the increasing availability of satellite imagery. A dramatic surge is observed from 2010 onwards, peaking significantly between 2019 and 2020, where cited references reached their peak (328 and 323, respectively). This trend quantitatively reflects a period of intense innovation and an expanding volume of foundational literature at the

intersection of computational techniques and agriculture.

The red line, representing the deviation from the 5-year median, highlights specific years where seminal works were published that significantly influenced subsequent research. This 5-year window is a standard parameter in RPYS utilised to smooth short-term annual fluctuations while retaining optimal sensitivity for detecting distinct seminal publication years. Notable positive deviations were recorded in 2001 (deviation 61) and 2011 (deviation 64), likely marking foundational studies in remote sensing methodologies. A remarkable spike occurred in 2013 (deviation 96), which corresponds to key papers on data assimilation that bridged the gap between crop models and satellite data. The sustained high deviations in 2018–2020 indicate that recent research is heavily building upon very contemporary studies, characterising a fast-moving, cutting-edge scientific front. The sharp decline after 2021 is a typical bibliometric artefact, as papers published in the most recent years have not yet accumulated sufficient historical citations to appear as base papers in this analysis.

Authors' keywords and keywords production over time

Fig. 9a presents a word cloud illustrating the most frequently occurring keywords in the bibliometric analysis of maize yield prediction research employing remote sensing and machine learning, where the relative size of each term reflects its frequency in the literature. The most prominent keywords are machine learning (95 occurrences) and remote sensing (91 occurrences), highlighting the strong emphasis on combining computational intelligence with Earth observation data. Other commonly recurring terms include maize (81 occurrences) and yield prediction (58 occurrences), underscoring the central thematic focus of the analysed studies. In contrast to earlier studies that were largely centred on crop simulation frameworks such as DSSAT, the current research landscape is increasingly dominated by

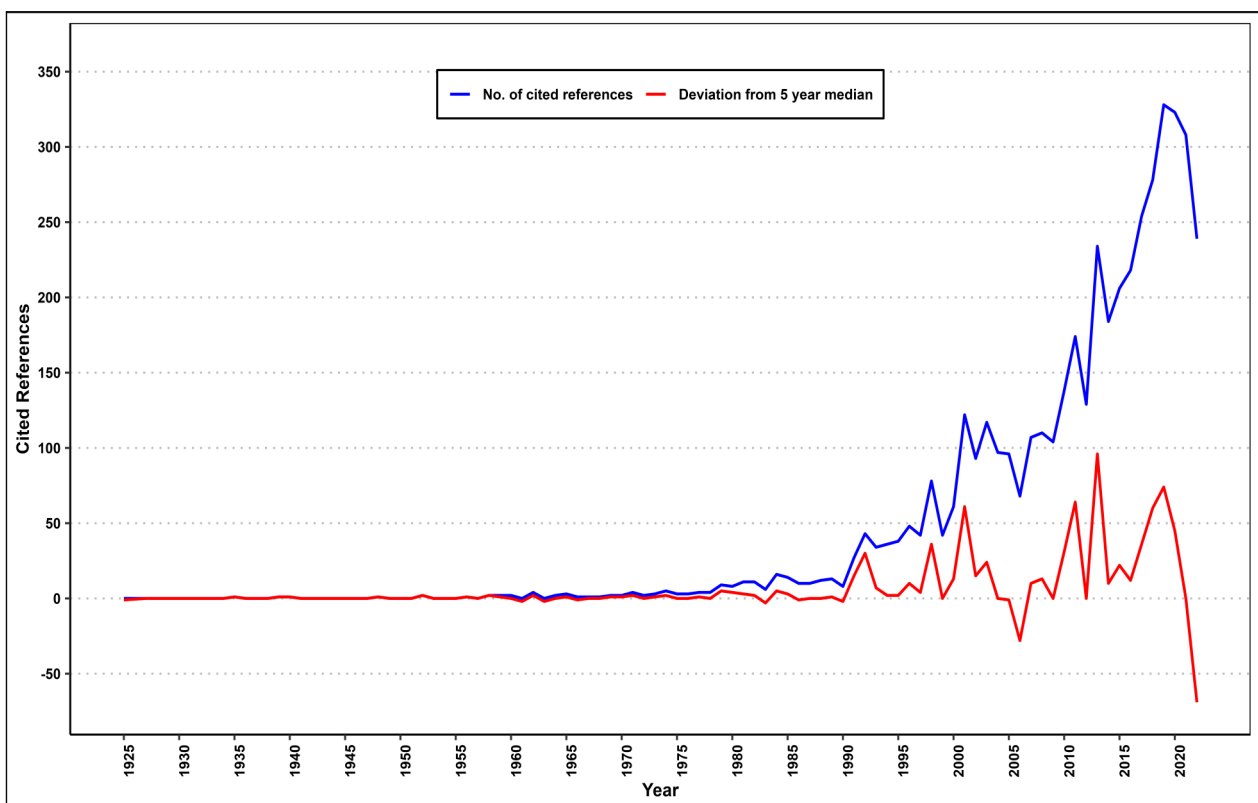


Fig. 8. Reference publication year spectroscopy (RPYS)

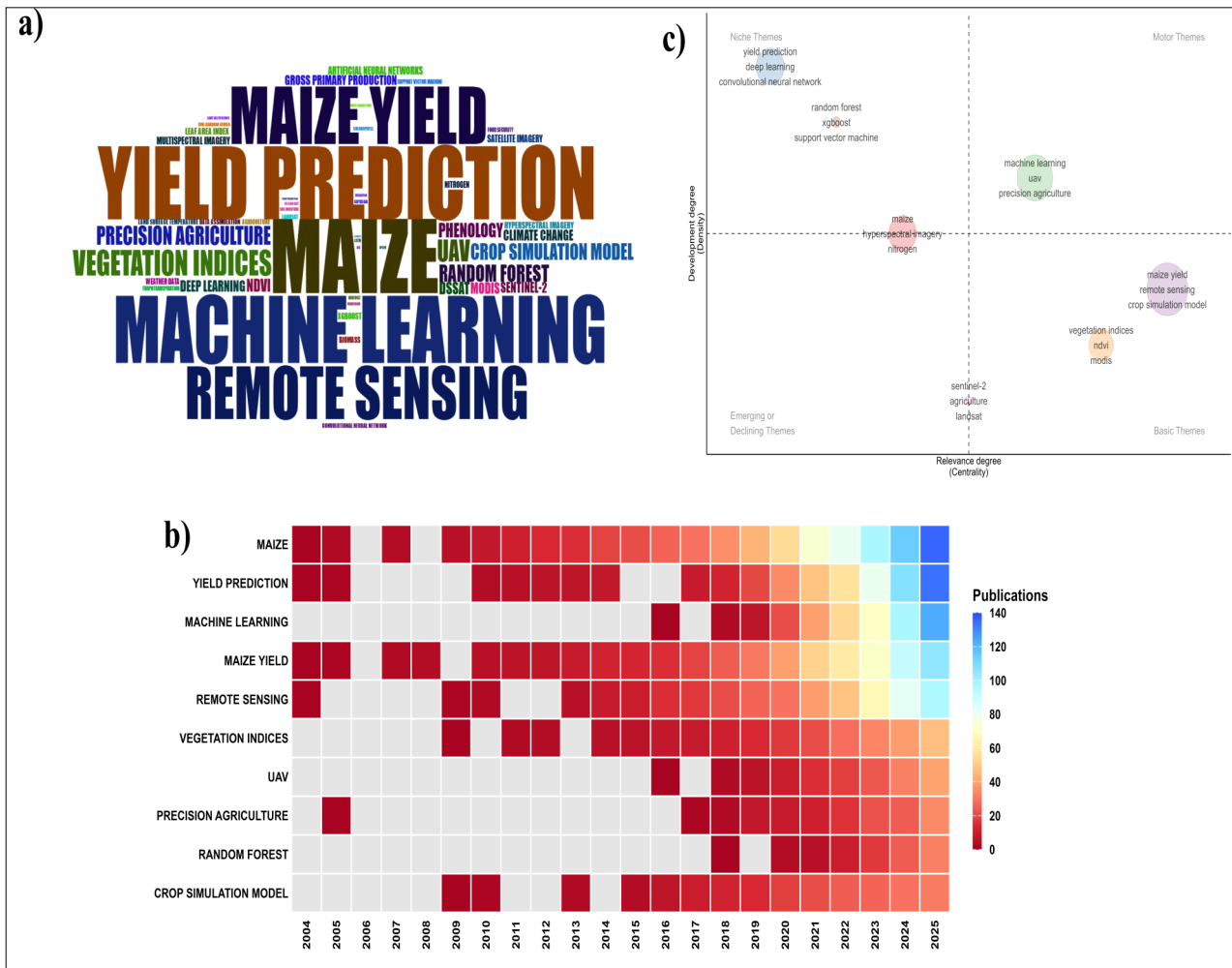


Fig. 9. Keyword and thematic analysis of maize yield prediction research: a. Word cloud of most frequent keywords; b. Trend topics and keyword production over time (heatmap); c. Thematic map of research themes based on density and centrality.

algorithm-driven terminology. Keywords such as random forest (26 occurrences) and deep learning (16 occurrences) now occupy a central position, reflecting the growing reliance on advanced machine learning techniques. At the same time, vegetation indices (24 occurrences) and NDVI (19 occurrences) continue to serve as core inputs, underscoring their enduring importance as foundational predictors within these models. The increasing appearance of terms like UAV (13 occurrences) and Sentinel-2 (15 occurrences) further points to a transition toward high-resolution, multi-platform data sources. Collectively, these keywords illustrate a multidisciplinary convergence of agronomy and data science, aimed at enhancing yield prediction accuracy through sophisticated computational approaches.

Analysis of keyword production over time reinforces this methodological transition. While fundamental terms such as Maize and Remote Sensing have remained consistently prominent, a clear paradigm shift is evident in the techniques employed. The heatmap depicts a sharp rise in artificial intelligence-related keywords from 2019 onward (Fig. 9b). Notably, Machine Learning experienced an exponential increase, growing from marginal representation in the early 2000s to more than 120 publications in 2025 alone. Similarly, deep learning and UAVs evolved from nascent concepts to dominant research themes over the past five years. The heatmap highlights the rapid uptake of specific machine learning algorithms, notably Random Forest and XGBoost, particularly during the 2022–2025 period. For instance, publications featuring Random Forest surged from just 4 in 2020 to 32 by 2025. Overall, this temporal evolution reflects a highly dynamic research field characterised by a

shift from the basic identification of vegetation indices, which reached 47 publications in 2025, toward the development of complex non-linear models capable of handling large spatiotemporal datasets. This trend is further evidenced by the growth of research categorised under precision agriculture, a keyword that concurrently grew from 9 to 34 publications between 2020 and 2025.

Thematic maps

The thematic map provides a quantitative snapshot of the conceptual structure of maize yield prediction research (Fig. 9c). Theme clusters were generated using the Louvain clustering algorithm (parameters: $n = 250$, minimum frequency = 2, community repulsion = 0.5) and plotted according to Callon Centrality (relevance degree) and Callon Density (development degree). The ‘maize yield’ cluster (Centrality = 1.406, Density = 43.655), along with remote sensing and crop simulation models, falls within the Basic Themes quadrant, indicating they are fundamental and widely connected across the field. Likewise, the ‘vegetation indices’ cluster (Centrality = 1.247) appears as a core building block, reaffirming the continued importance of spectral information. The Motor Themes, characterised by high relevance and strong development, are led by the ‘machine learning’ cluster (Centrality = 1.185, Density = 44.380), encompassing UAV and precision agriculture, which represent the mature, integrated driving forces of the field. In contrast, highly developed Niche Themes such as the ‘yield prediction’ (Density = 50.952) and ‘random forest’ (Density = 44.723) clusters, which include deep learning, CNN and XGBoost, represent

methodologically advanced approaches explored as specialised techniques rather than fully integrated components. The emerging or declining quadrant includes the 's'entinel-2' cluster (Centrality = 0.893, Density = 39.494). Furthermore, knowledge diffusion across the network was quantified using betweenness centrality. 'Machine learning' (Betweenness = 5394.19) and 'maize' (Betweenness = 5050.57) exhibited the highest betweenness values, empirically confirming their roles as primary central conduits for bridging and transferring methodological knowledge across distinct agronomic and computational sub-domains.

Collaboration among authors, institutions and countries

Fig. 10a depicts the author collaboration network, where impacts represent individual researchers and connecting edges indicate co-authorship relationships. Prominent authors such as Zhang X, Wang H and Li Y appear as large, highly connected associates, highlighting their roles as key intellectual hubs that enable substantial knowledge exchange within the field. The presence of distinct colour-coded clusters points to closely knit collaborative groups, often aligned by shared institutions or thematic specialisations such as deep learning and satellite data integration. Stronger and thicker links, for example, between Zhang Z and Ma Y, denote frequent and influential research collaborations. Overall, the network reflects a shift from earlier dominance by individual crop modellers to a more distributed, data-driven collaborative structure in agronomic research.

Fig. 10b illustrates the institutional collaboration network, in which the University of Illinois Urbana-Champaign stands out as the most central and highly connected institution, emphasising its leading role in bridging computational science and agriculture. Strong collaborative ties with major Chinese institutions, including China Agricultural University and Beijing Normal University, underscore the importance of transnational partnerships in

advancing this research area. Additional clusters centred on the University of Wisconsin-Madison and the University of Chinese Academy of Sciences represent specialised research groups focusing on remote sensing. Collectively, these institutions function as key conduits for global knowledge exchange in AI-based maize yield prediction.

Fig. 10c-10d presents the country-level collaboration network, revealing a pronounced dual dominance of the USA and China. The exceptionally thick link between these two countries indicates a strong exchange of methodologies and technologies, surpassing other international collaborations. Brazil emerges as a distinct cluster, reflecting its position as a major maize producer, developing region-specific remote sensing applications. Countries such as India, Germany and Australia also appear as important contributors, particularly in adapting and validating global models under local agro-climatic conditions. The dense web of connections highlights a coordinated global effort to enhance food security, with innovations originating in the USA and China increasingly diffused and applied across agricultural systems worldwide.

Conclusion

This bibliometric analysis provides a comprehensive overview of maize yield prediction using remote sensing and machine learning. Uniquely, this study quantifies the structural evolution and knowledge diffusion within this interdisciplinary domain, demonstrating exactly how foundational remote sensing concepts have integrated with advanced computational algorithms over the past two decades. The analysis revealed a rapid expansion in both the volume and impact of publications from 2000 to 2025, reflecting the growing global relevance of these combined

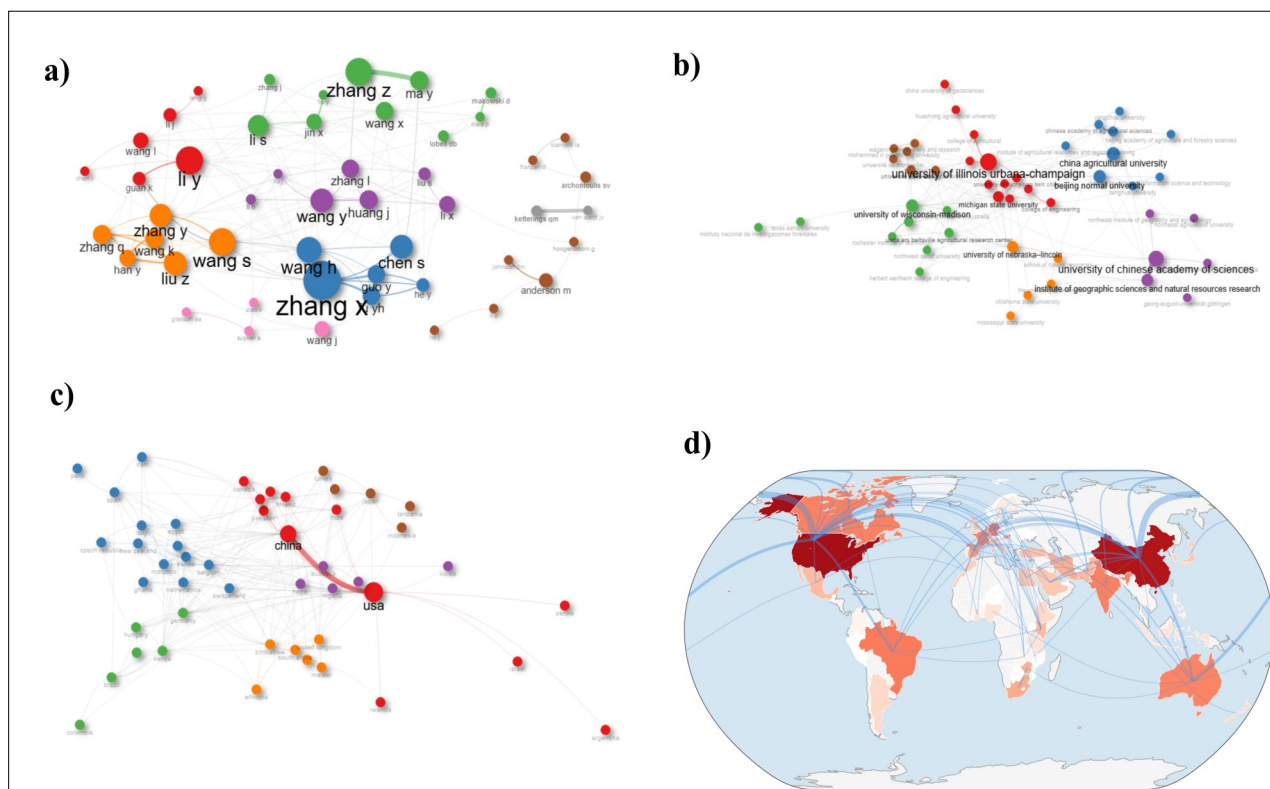


Fig. 10. Global collaboration networks and geographic mapping [Generated by using Biblioshiny (Bibliometrix package, R software), default map options]: a. Authors' collaboration network; b. Institutions' collaboration network; c. Countries' collaboration network; d. Countries' collaboration map.

technologies. The collaborative nature of the field is demonstrated by research output dominated by leading nations such as the USA and China, alongside rising contributions from India and Brazil. Furthermore, the thematic mapping identified a distinct paradigm shift as conventional vegetation indices were functioning as basic building blocks for highly developed, data-driven approaches like random forest and deep learning. This underscores a targeted research shift towards high-resolution and hybrid modelling frameworks designed to capture complex crop dynamics. Thus, the synergy of remote sensing and machine learning remains a cornerstone for modern precision agriculture. Future research should focus on improving model interpretability and integrating multi-source data to enhance predictive performance, thereby contributing to global food security and sustainable agricultural management.

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Authors' contributions

SS¹ and SP conceived and designed the study, SS¹ performed the data collection, software implementation, formal bibliometric analysis and drafted the original manuscript. SP provided supervision, resources and project administration. ST, PCP, MG, CSR and KPR participated in the validation of results and critical review of the manuscript. NSS and SS² assisted in data curation and editing. All authors read and approved the final manuscript [SS¹ stands for Sivakumar Sakthivel and SS² for Sakthivel Satheesh].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Gemini for Grammar checking and paraphrasing. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

- Erenstein O, Jaleta M, Sonder K, Mottaleb K, Prasanna BM. Global maize production, consumption and trade: trends and R&D implications. *Food Secur.* 2022;14(5):1295–319. <https://doi.org/10.1007/s12571-022-01288-7>
- Chitsiko RJ, Mutanga O, Dube T, Kutuywayo D. Review of current models and approaches used for maize crop yield forecasting in sub-Saharan Africa and their potential use in early warning systems. *Phys Chem Earth Parts A/B/C.* 2022;127:103199. <https://doi.org/10.1016/j.pce.2022.103199>
- Zelenák A, Szabó A, Nagy J, Nyéki A. Using the CERES-Maize model to simulate crop yield in a long-term field experiment in Hungary. *Agronomy.* 2022;12(4):785. <https://doi.org/10.3390/agronomy12040785>
- Jabed MA, Azmi Murad MA. Crop yield prediction in agriculture: a comprehensive review of machine learning and deep learning approaches, with insights for future research and sustainability. *Heliyon.* 2024;10(24):e40836. <https://doi.org/10.1016/j.heliyon.2024.e40836>
- Khaki S, Wang L. Crop yield prediction using deep neural networks. *Front Plant Sci.* 2019;10:621. <https://doi.org/10.3389/fpls.2019.00621>
- Lizaso JI, Ruiz-Ramos M, Rodríguez L, Gabaldon-Leal C, Oliveira JA, Lorite IJ, et al. Modeling the response of maize phenology, kernel set and yield components to heat stress and heat shock with CSM-IXIM. *Field Crops Res.* 2017;214:239–54. <https://doi.org/10.1016/j.fcr.2017.09.019>
- Chang Y, Latham J, Licht M, Wang L. A data-driven crop model for maize yield prediction. *Commun Biol.* 2023;6(1):439. <https://doi.org/10.1038/s42003-023-04833-y>
- Sharma A, Jain A, Gupta P, Chowdary V. Machine learning applications for precision agriculture: a comprehensive review. *IEEE Access.* 2021;9:4843–73. <https://doi.org/10.1109/ACCESS.2020.3048415>
- Van Klompenburg T, Kassahun A, Catal C. Crop yield prediction using machine learning: a systematic literature review. *Comput Electron Agric.* 2020;177:105709. <https://doi.org/10.1016/j.compag.2020.105709>
- Paudel D, Boogaard H, De Wit A, Janssen S, Osinga S, Pylaniadis C, et al. Machine learning for large-scale crop yield forecasting. *Agric Syst.* 2021;187:103016. <https://doi.org/10.1016/j.agsy.2020.103016>
- Lobell DB, Thau D, Seifert C, Engle E, Little B. A scalable satellite-based crop yield mapper. *Remote Sens Environ.* 2015;164:324–33. <https://doi.org/10.1016/j.rse.2015.04.021>
- Becker-Reshef I, Justice C, Sullivan M, Vermote E, Tucker C, Anyamba A, et al. Monitoring global croplands with coarse resolution earth observations: the Global Agriculture Monitoring (GLAM) project. *Remote Sens.* 2010;2(6):1589–609. <https://doi.org/10.3390/rs2061589>
- Momenpour SE, Bazgeer S, Moghbel M. A bibliometric analysis of the literature on crop yield prediction: insights from previous findings and prospects for future research. *Int J Biometeorol.* 2024;68(5):829–42. <https://doi.org/10.1007/s00484-024-02628-2>
- Xu J, Song Y, Rui Z, Zhang Z, Hu C, Wang L, et al. Trend analysis of the application of multispectral technology in plant yield prediction: a bibliometric visualization analysis (2003–2024). *Front Sustain Food Syst.* 2025;9:1513690. <https://doi.org/10.3389/fsufs.2025.1513690>
- Matyukira C, Mhangara P. Advances in vegetation mapping through remote sensing and machine learning techniques: a scientometric review. *Eur J Remote Sens.* 2024;57(1):2422330. <https://doi.org/10.1080/22797254.2024.2422330>
- Ali A, Perna S. Sustainability indicators in agriculture: a review and bibliometric analysis using Scopus database. *J Agric Environ Int Dev (JAEID).* 2021;115(2):5–21. <https://doi.org/10.36253/jaeid-12083>
- Abiola WA, Diogo RVC, Tovihoudji PG, Mien AK, Schalla A. Research trends on biochar-based smart fertilizers as an option for the sustainable agricultural land management: bibliometric analysis and review. *Front Soil Sci.* 2023;3:1136327. <https://doi.org/10.3389/fsoil.2023.1136327>
- Pan X, Yan E, Cui M, Hua W. Examining the usage, citation and diffusion patterns of bibliometric mapping software: a comparative study of three tools. *J Informetr.* 2018;12(2):481–93. <https://doi.org/10.1016/j.joi.2018.03.005>
- Chen Z, Gao Y, Chen J, Yang L, Zeng S, Su Y, et al. Global bibliometric analysis of research on the application of biochar in forest soils. *Forests.* 2023;14(11):2238. <https://doi.org/10.3390/f14112238>
- Aria M, Cuccurullo C. bibliometrix: an R-tool for comprehensive

- science mapping analysis. *J Informetr.* 2017;11(4):959–75. <https://doi.org/10.1016/j.joi.2017.08.007>
21. Visser M, Van Eck NJ, Waltman L. Large-scale comparison of bibliographic data sources: Scopus, Web of Science, Dimensions, Crossref and Microsoft Academic. *Quant Sci Stud.* 2021;2(1):20–41. https://doi.org/10.1162/qss_a_00112
 22. Pavithra G, Sakthivel S, Kalaimathi V, Hariprasanth T, Ajith D, Adhisankaran K, et al. Global research trends of natural fibers: a bibliometric review from 2000 to 2023. *Plant Sci Today.* 2025;12 (sp4). <https://doi.org/10.14719/pst.8668>
 23. Kalaimathi V, Geethalakshmi V, Parasuraman P, Kathirvelan P, Swaminathan C. A bibliometric analysis of the Journal of Agrometeorology (JAM) from 2008 to 2022. *J Agrometeorol.* 2024;26 (1):1–17. <https://doi.org/10.54386/jam.v26i1.2525>
 24. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021;372:n71. <https://doi.org/10.1136/bmj.n71>
 25. Yang JM, Tseng SF, Won YL. A bibliometric analysis on data mining using Bradfords' Law. In: Juang J, editor. *Proceedings of the 3rd International Conference on Intelligent Technologies and Engineering Systems (ICITES2014)*. (Lecture Notes in Electrical Engineering). Cham: Springer; 2016. p. 613–20. https://doi.org/10.1007/978-3-319-17314-6_78
 26. Amanullah A, Rajeswari S, Gul S. Testing the applicability of Lotka's Law, Bradfords' Law and Zips' Law on gastritis research output. *DESIDOC J Libr Inf Technol.* 2025;45(4):378–94. <https://doi.org/10.14429/djlit.21019>
 27. Perianes-Rodriguez A, Waltman L, Van Eck NJ. Constructing bibliometric networks: a comparison between full and fractional counting. *J Informetr.* 2016;10(4):1178–95. <https://doi.org/10.1016/j.joi.2016.10.006>
 28. Ines AVM, Das NN, Hansen JW, Njoku EG. Assimilation of remotely sensed soil moisture and vegetation with a crop simulation model for maize yield prediction. *Remote Sens Environ.* 2013;138:149–64. <https://doi.org/10.1016/j.rse.2013.07.018>
 29. Liu S, Yang JY, Zhang XY, Drury CF, Reynolds WD, Hoogenboom G. Modelling crop yield, soil water content and soil temperature for a soybean–maize rotation under conventional and conservation tillage systems in Northeast China. *Agric Water Manag.* 2013;123:32–44. <https://doi.org/10.1016/j.agwat.2013.03.001>
 30. Jiang H, Hu H, Zhong R, Xu J, Xu J, Huang J, et al. A deep learning approach to conflating heterogeneous geospatial data for corn yield estimation: a case study of the US Corn Belt at the county level. *Glob Chang Biol.* 2020;26(3):1754–66. <https://doi.org/10.1111/gcb.14885>
 31. Shahhosseini M, Hu G, Archontoulis SV. Forecasting corn yield with machine learning ensembles. *Front Plant Sci.* 2020;11:1120. <https://doi.org/10.3389/fpls.2020.01120>
 32. Marques Ramos AP, Prado Osco L, Elis Garcia Furuya D, Nunes Gonçalves W, Cordeiro Santana D, Pereira Ribeiro Teodoro L, et al. A random forest ranking approach to predict yield in maize with UAV-based vegetation spectral indices. *Comput Electron Agric.* 2020;178:105791. <https://doi.org/10.1016/j.compag.2020.105791>
 33. Rigden AJ, Mueller ND, Holbrook NM, Pillai N, Huybers P. Combined influence of soil moisture and atmospheric evaporative demand is important for accurately predicting US maize yields. *Nat Food.* 2020;1(2):127–33. <https://doi.org/10.1038/s43016-020-0028-7>
 34. Kang Y, Ozdogan M, Zhu X, Ye Z, Hain C anderson M. Comparative assessment of environmental variables and machine learning algorithms for maize yield prediction in the US Midwest. *Environ Res Lett.* 2020;15(6):064005. <https://doi.org/10.1088/1748-9326/ab7df9>
 35. Kushairi N, Ahmi A. Flipped classroom in the second decade of the millennia: a bibliometrics analysis with Lotka's law. *Educ Inf Technol.* 2021;26(4):4401–31. <https://doi.org/10.1007/s10639-021-10457-8>
 36. Zhang L, Zhang Z, Luo Y, Cao J, Xie R, Li S. Integrating satellite-derived climatic and vegetation indices to predict smallholder maize yield using deep learning. *Agric For Meteorol.* 2021;311:108666. <https://doi.org/10.1016/j.agrformet.2021.108666>
 37. Ma Y, Zhang Z, Kang Y, Özdoğan M. Corn yield prediction and uncertainty analysis based on remotely sensed variables using a Bayesian neural network approach. *Remote Sens Environ.* 2021;259:112408. <https://doi.org/10.1016/j.rse.2021.112408>
 38. Guo Y, Wang H, Wu Z, Wang S, Sun H, Senthilnath J, et al. Modified red blue vegetation index for chlorophyll estimation and yield prediction of maize from visible images captured by UAV. *Sensors.* 2020;20(18):5055. <https://doi.org/10.3390/s20185055>
 39. Johnson DM. An assessment of pre- and within-season remotely sensed variables for forecasting corn and soybean yields in the United States. *Remote Sens Environ.* 2014;141:116–28. <https://doi.org/10.1016/j.rse.2013.10.027>
 40. Shahhosseini M, Hu G, Huber I, Archontoulis SV. Coupling machine learning and crop modeling improves crop yield prediction in the US Corn Belt. *Sci Rep.* 2021;11(1):1606. <https://doi.org/10.1038/s41598-020-80820-1>
 41. Jin Z, Azzari G, You C, Di Tommaso S, Aston S, Burke M, et al. Smallholder maize area and yield mapping at national scales with Google Earth Engine. *Remote Sens Environ.* 2019;228:115–28. <https://doi.org/10.1016/j.rse.2019.04.016>
 42. Khanal S, Fulton J, Klopfenstein A, Douridas N, Shearer S. Integration of high-resolution remotely sensed data and machine learning techniques for spatial prediction of soil properties and corn yield. *Comput Electron Agric.* 2018;153:213–25. <https://doi.org/10.1016/j.compag.2018.07.016>
 43. Baek C, Doleck T. A bibliometric analysis of the papers published in the Journal of Artificial Intelligence in Education from 2015–2019. *Int J Artif Intell.* 2020;2(1):67. <https://doi.org/10.3991/ijai.v2i1.14481>
 44. Geipel J, Link J, Claupein W. Combined spectral and spatial modeling of corn yield based on aerial images and crop surface models acquired with an unmanned aircraft system. *Remote Sens.* 2014;6(11):10335–55. <https://doi.org/10.3390/rs61110335>
 45. Battude M, Al Bitar A, Morin D, Cros J, Huc M, Marais Sicre C, et al. Estimating maize biomass and yield over large areas using high spatial and temporal resolution Sentinel-2 like remote sensing data. *Remote Sens Environ.* 2016;184:668–81. <https://doi.org/10.1016/j.rse.2016.07.030>
 46. Uno Y, Prasher SO, Lacroix R, Goel PK, Karimi Y, Viau A, et al. Artificial neural networks to predict corn yield from Compact Airborne Spectrographic Imager data. *Comput Electron Agric.* 2005;47(2):149–61. <https://doi.org/10.1016/j.compag.2004.11.014>

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