

A comprehensive bibliometric review of DSSAT applications in Maize yield prediction

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Abstract

Maize plays a crucial role in global food security, contributing significantly to food grain production, industrial products, livestock feed and biofuel production. Accurate maize yield prediction is highly essential for optimizing agricultural practices, ensuring sustainable production and mitigating the risks related to climate change, soil health and agricultural variability. This bibliometric review analyses global research trends on DSSAT applications in maize yield prediction from 1995 to 2024 based on 368 peer-reviewed articles from 131 journals. The analysis revealed consistent growth in publications, with 12.93% annual growth, highlighting the increasing interest in this field. The USA leads with 661 articles (27.4%), followed by China with 371 articles (15.5%) and India (156 articles). International collaboration is significant, with 42.66% of publications involving co-authorship across countries. Key authors include Hoogenboom G (48 articles, 2,591 citations) and Jones JW (17 articles, 1,134 citations). Major research themes include climate change, crop modelling, irrigation and nitrogen management, with increasing focus on adaptation strategies and model inter-comparison. Citation analysis shows a peak in impact in 2013, with 1,003 citations, reflecting the growing importance of DSSAT. This study highlights DSSAT's role in addressing global agricultural challenges and its critical contribution in optimizing maize yield predictions amid global climate change.

Abbreviations

CERES : Crop Environment Resource Synthesis

DSSAT : Decision Support System for Agrotechnology Transfer

MCP : Multiple-Country Publications

PRISMA : Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RPYS : Reference Publication Year Spectroscopy

SCP : Single-Country Publications

Introduction

The demand for food continues to increase in the face of a rapidly growing global population. Thus, predicting crop yields is an inevitable factor for agricultural planning and food security. Crop yield prediction plays a pivotal role in ensuring that adequate resources such as water, fertilizer and labour are allocated efficiently to meet the food requirements of expanding population (Zelenak et al., 2022). Accurate yield estimations

are essential for farmers, policymakers and agricultural stakeholders to mitigate the risks associated with climate variability, pest infestations and market price fluctuations (Jabed and Azmi Murad, 2024). Furthermore, these predictions are invaluable for food distribution systems and trade policies, to ensure global food security (Khaki and Wang, 2019).

Maize is among the most widely grown and economically significant crops worldwide. As a staple crop, maize contributes not only to the global food supply but also to industrial products, livestock feed and biofuel production. With its wide distribution across the globe, maize is integral to economic growth of many countries (Erenstein *et al.*, 2022). Accurate maize yield predictions are essential for optimising agricultural practices and ensuring sustainable production, particularly because it is susceptible to varying climatic conditions, soil health and changing agricultural practices (Chitsiko *et al.*, 2022). Hence, effective yield predictions can help minimise losses, optimise inputs and boost overall productivity. The challenge of accurately predicting maize yields is compounded by complex interactions between climatic variables, soil conditions and farming practices (Chang *et al.*, 2023). Therefore, advancements in agricultural modelling and simulation tools have become increasingly valuable for improving precision and reliability of these predictions (Gupta *et al.*, 2022). The Decision Support System for Agrotechnology Transfer (DSSAT) model is among the most widely used tools for crop modelling. This model serves as an important tool for simulating crop performance and provides critical insights into the impact of environmental factors and management practices on maize yield (Thimmareddy *et al.*, 2024). The DSSAT model is a robust crop modelling tool that integrates biophysical, environmental and management data to simulate crop growth and yield under a variety of conditions. The system was built on a series of individual crop models, including the CERES-MAIZE model, specifically designed for maize (Jones and Kiniry, 1986). These models simulate interactions between soil, climate and plant growth, enabling users to assess how different factors, *viz.*, soil type, temperature, rainfall, irrigation and crop management, influence maize yield (Jones *et al.*, 2003). DSSAT's ability to integrate a broad range of variables and simulate different crop management strategies makes it a versatile tool in agricultural research. It has been used in both the small- and large-scale farming systems, offering invaluable insights into the potential outcomes of various interventions (Kumar *et al.*, 2024).

Researchers have utilised DSSAT for a wide range of applications, including studying the impacts of climate change on maize yield (Ngwira *et al.*, 2014; Abera *et al.*, 2018; Yasin *et al.*, 2022), optimising irrigation schedules (Bai *et al.*, 2022), determining the best planting and harvesting dates (Rugira *et al.*, 2021; Kumar *et al.*, 2024) and evaluating the effectiveness of soil management practices (Jiang *et al.*, 2019; Gobezie *et al.*, 2025). The tool's flexibility and adaptability have made it an essential tool in agricultural modelling worldwide. The

global use of DSSAT in maize yield prediction underscores its importance as a decision-support tool. It is particularly valuable in regions where maize is a major crop and the risks associated with climate variability and resource scarcity are high. By simulating various scenarios, DSSAT assists stakeholders in understanding how changes in environmental conditions or management practices affect maize yields, thus aiding the development of more sustainable and resilient cropping systems (Kumar *et al.*, 2024). With the growing interest in maize yield prediction using DSSAT, this bibliometric analysis aims to systematically assess the research trend in this field which is a valuable tool for examining research trends, key contributors, influential publications and thematic developments (Asritha *et al.*, 2024; Kalamathi *et al.*, 2024). Bibliometric methods can enable an in-depth understanding of the evolution of maize yield prediction research, methodologies employed and contributions of the global research community. The primary goal of this bibliometric review is to map the growth of research on maize yield prediction using DSSAT over the past few decades. This study analyses articles published between 1995 and 2024, focusing on literature indexed in Scopus. It examines bibliometric indicators such as publication trends, citation patterns and author collaboration networks to uncover patterns in DSSAT-based maize yield prediction research. The study aims to identify influential authors, institutions, journals and countries and track emerging research themes thus shaping the future of DSSAT applications. The findings will provide valuable insights for researchers and policymakers, guiding future research directions and highlighting areas for further exploration to optimize DSSAT model in maize yield prediction and address global climatic change.

Methodology

Bibliometric analysis is a universally adopted approach to systematically explore research trends, thematic patterns and relationships within authors, institutions and countries, based on published scientific literature (Ali and Perna, 2021; Abiola *et al.*, 2023). Commonly available tools for bibliometric analysis are Bibexcel, Biblioshiny, BiblioMaps, CiteSpace, CitNetExplorer, SciMAT, Sci² Tool and VOS viewer (Pan *et al.*, 2018; Chen *et al.*, 2023). Moral-Muñoz *et al.* (2020) reported that Biblioshiny is a better tool, known for its innovative features and consistent updates. Therefore, this study utilized the R-based interactive Biblioshiny application for its extensive functionality and user-friendly interface, which facilitated a comprehensive analysis.

Software used

Bibliometric analysis was carried out using Biblioshiny, a shiny application of the *Bibliometrix* R package (version 4.3.3) (Aria and Cuccurullo, 2017). For better visual representation, additional visualizations were created using *ggplot2* package (version 3.5.1) in R (version 4.4.1) (R core team, 2024) within the RStudio Integrated Development Environment (version 2024.04.01) for improved reproducibility and efficient data management. Preliminary data cleaning was performed using Microsoft Excel.

Data Collection and Screening

Academic databases viz., Google Scholar, Web of Science, Scopus and PubMed, are well known for their structured literature collection from diverse sources. Scopus database was selected for this study because of its extensive coverage of peer-reviewed literature and precise citation metrics (Visser et al., 2021). A systematic keyword search was performed to identify articles related to objective, which focuses on maize yield prediction using DSSAT model. The search string used in Scopus was TITLE-ABS-KEY (("maize" OR "corn") AND

("DSSAT" OR "Decision Support System for Agrotechnology Transfer") AND ("yield")) AND (LIMIT-TO (PUBYEAR < 2025)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")). Articles were screened and systematically selected based on the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Fig. 1) (Page et al., 2021). Initially, 443 records were obtained from Scopus. After applying the exclusion criteria to refine the literature in accordance with the objective, 368 articles published between 1995 and 2024 were retained. These final records were downloaded in the CSV format for further analysis.

Data analysis

The final dataset (368 articles) published between 1995 and 2024 was analysed using Biblioshiny. Key bibliometric indicators were systematically extracted to cover various aspects, such as publication trends, citation patterns, author productivity, collaboration networks and keyword co-occurrence. Annual trends in publications and citations, as well as geographic distribution, to identify global leaders contributing to maize yield prediction research using DSSAT model were examined. Further, Author-level and keyword-based analyses were conducted to provide an overview of collaborative networks within the scholarly community and to identify emerging areas of research related to maize yield estimation.

Results and discussion

Publication Overview

Bibliometric analysis confirmed the growing importance of crop simulation models in yield predictions under varying environmental conditions. This study covered 368 research articles published through 131 sources (journals) between 1995 and 2024 (Table 1). Research on maize yield prediction using DSSAT model has shown consistent growth, demonstrated by an annual growth rate of 12.93%. This growth can also be substantiated by the average age of articles (7.79 years). On an average, each article received 28.8 citations, with 10,600 total citations, corresponding to about 2.98 citations per year, indicating the emerging need for models under climate change. In addition, 1,370 authors have published their research articles on maize yield prediction using the DSSAT model. It is important to note that there were 5.73 co-authors per article and 0.269 articles per author. The analysis appears to corroborate importance of international collaboration, as 42.66 per cent of the papers involved international

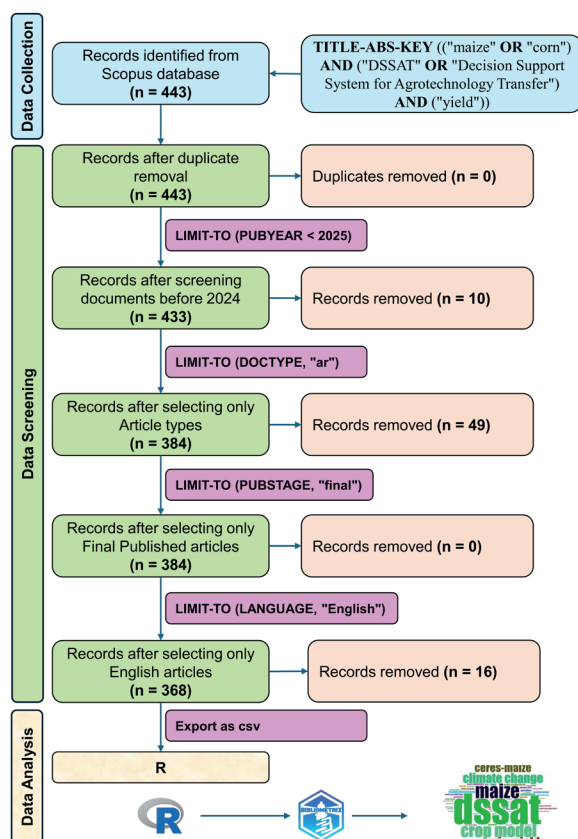


Fig. 1 - PRISMA flowchart for bibliometric analysis of Maize yield prediction using DSSAT

Table 1 - Publication overview of research on Maize yield prediction using DSSAT

Description	Results	Description	Results
Main information about the data		Authors collaboration	
Timespan	1995:2024	Authors	1,370
Sources	131	Author Appearances	2,107
Articles	368	Single-authored article	7
Annual Growth Rate %	12.93	Articles per author	0.269
Article Average Age	7.79	Co-authors per article	5.73
Total citations	10,600	International co-authorships %	42.66
Average citations per article	28.80		
Average citations per year per article	2.98		
Total references cited	17,724		

cooperation. The published research works were reported to have 17,724 references cited, supporting extensive reliance 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 number of published papers and citations. Analysis from 1995 to 2024 revealed a steady increase in research publications, with significant peaks during 2013, 2019 and 2021 (Fig. 2). Citation trends were in good agreement with the publication trends, with high citation impacts around the mid-2000s and recent years. Articles published in 2000 was found to

have the highest mean citations (129 mean citations/article), whereas the highest mean citations per year was recorded in 2013 (7.01) (Table 2). The highest number of citations was recorded in 2013 (1,003 citations) indicating impactful research contributions during that period. There was a pronounced increase in publication volume from 2020 to 2024, reflecting the growing relevance and popularity of the DSSAT model in maize yield prediction. In 2021, the number of publications peaked significantly, with 40 articles, followed by 36 articles in 2023. These recent peaks substantiate the growing advancements in computational modelling, broader accessibility of DSSAT and heightened global focus on improved yield prediction and agricultural sustainability.

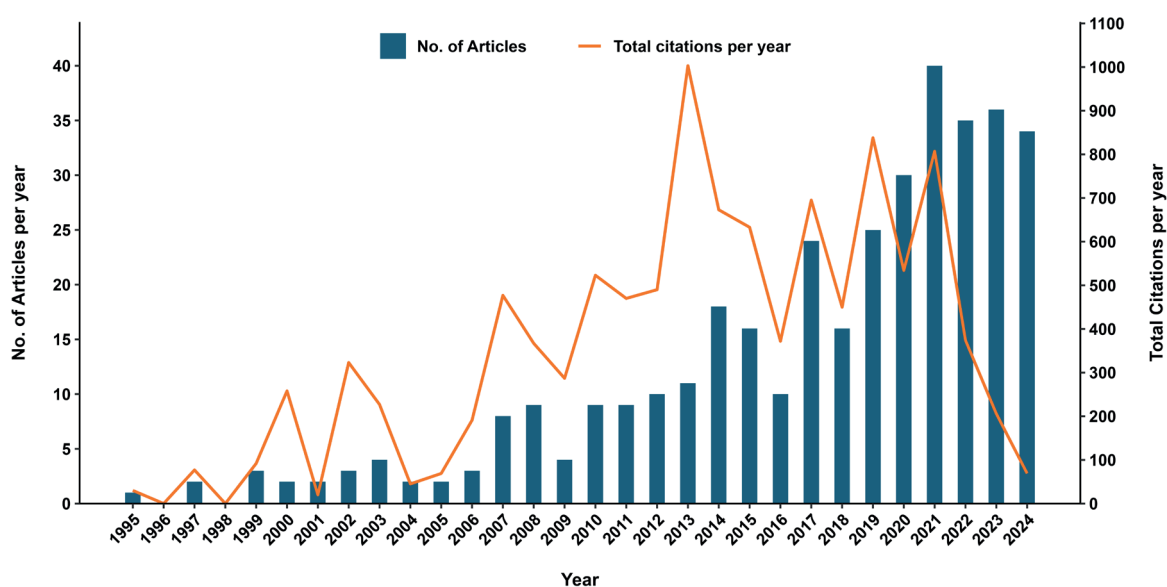
**Fig. 2 - Annual scientific production of articles and Total citations per year related to Maize yield prediction using DSSAT**

Table 2 - Annual scientific production and citation trends in Maize yield prediction using DSSAT

Year	No. of Articles	Total citations	Mean total citations per article	Citable years	Mean total citations per year
1995	1	30	30.00	31	0.97
1996	0	0	-	30	-
1997	2	77	38.50	29	1.33
1998	0	0	-	28	-
1999	3	92	30.67	27	1.14
2000	2	258	129.00	26	4.96
2001	2	20	10.00	25	0.40
2002	3	323	107.67	24	4.49
2003	4	227	56.75	23	2.47
2004	2	45	22.50	22	1.02
2005	2	69	34.50	21	1.64
2006	3	191	63.67	20	3.18
2007	8	477	59.63	19	3.14
2008	9	367	40.78	18	2.27
2009	4	287	71.75	17	4.22
2010	9	523	58.11	16	3.63
2011	9	470	52.22	15	3.48
2012	10	490	49.00	14	3.50
2013	11	1,003	91.18	13	7.01
2014	18	673	37.39	12	3.12
2015	16	633	39.56	11	3.60
2016	10	372	37.20	10	3.72
2017	24	695	28.96	9	3.22
2018	16	450	28.13	8	3.52
2019	25	838	33.52	7	4.79
2020	30	534	17.80	6	2.97
2021	40	807	20.18	5	4.04
2022	35	374	10.69	4	2.67
2023	36	206	5.72	3	1.91
2024	34	69	2.03	2	1.01
Total	368	10,600	28.80		2.98

Publication and Impact Metrics Analysis of Top 10 Journals

The analysis of journal performance revealed substantial variations in impact and citation metrics across these journals (Table 3). A total of 131 sources has contributed to research works related to Maize yield prediction using DSSAT. *Agricultural Water Management* emerged as the leading journal with an H-index of 21, a G-index of 36 and 1,515 citations across 36 published papers, demonstrating its sustained and significant academic influence. *Agricultural Systems* fol-

lowed closely with a H-index of 18, a G-index of 23 and 1,130 citations, further reflecting its impact within the field. Journals such as the *European Journal of Agronomy* (H-index: 13, G-index: 18) and *Field Crops Research* (H-index: 13, G-index: 15) evinced moderate scholarly influence with 855 and 728 citations, respectively, highlighting their steady but slower citation growth. *Agronomy* (H-index: 8, G-index: 12) demonstrated rapid early growth, as evidenced by an M-index of 1.143, indicating a strong potential for future impacts in the field of yield prediction. Additionally, *Mitigation and*

Table 3 - Publication and Impact Metrics of the Top 10 Journals

Source	H index	G index	M index	TC	NP	PY start
Agricultural Water Management	21	36	0.875	1515	36	2002
Agricultural Systems	18	23	0.667	1130	23	1999
European Journal of Agronomy	13	18	0.591	855	18	2004
Field Crops Research	13	15	0.565	728	15	2003
Agricultural and Forest Meteorology	10	11	0.385	622	11	2000
Agronomy	8	12	1.143	164	17	2019
Agronomy Journal	8	11	0.5	361	11	2010
Transactions of the ASABE	8	12	0.421	368	12	2007
Mitigation and Adaptation Strategies for Global Change	6	6	0.207	261	6	1997
Climate Research	5	5	0.172	342	5	1997

*TC – Total Citations; NP- Number of Papers (articles); PY start– Publication Year started from

Adaptation Strategies for Global Change and *Climate Research* showed lower H-index

(6 and 5) and less total citations (261 and 342, respectively), yet it continues to provide valuable contributions in maize yield prediction using the DSSAT model. This dataset highlights the varying levels of impact within the field, from well-established leading journals to newer, more specialized sources.

Journal's Contribution based on Bradford's Law

Bradford's Law is a bibliometric tool used to identify core journals that contribute the most to a particular subject area (Yang et al., 2016; Yazdi et al., 2023). In the context of Maize yield prediction using DSSAT, this law categorizes journals into three distinct zones based on their scholarly output. Zone 1 consisted of 7 journals with 132 articles (35.87 %) (Table 4). The top seven journals viz., *Agricultural Water Management*, *Agricultural Systems*, *European Journal of Agronomy*, *Agronomy*, *Field Crop Research*, *Transactions of the ASABE* and *Agricultural and Forest Meteorology*, were pivotal to the field, making substantial contributions to the body of research (Fig. 3a). Zone 2, which contains 25 journals, contributed 15 articles (31.25% of the total publications), while Zone 3 consists of 99 journals with

122 articles (32.88%). Although Zone 3 journals are numerous, they each contributed fewer articles, representing more peripheral sources within the field. This distribution demonstrated how a small group of core journals (Zone 1) could significantly shape the direction of research in Maize yield prediction, 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 and guiding future research efforts.

Journal publication trends over time on Maize yield prediction using DSSAT

The production trends of the top five journals (Fig. 3b) related to Maize yield prediction using DSSAT over time revealed a steady increase in article output across all journals. *Agricultural Water Management* started with no publications related to maize yield prediction using DSSAT from 1995 to 1999, has shown gradual growth, reaching 36 articles from 2002 to 2024. This increase reflects the growing importance of water-related studies in agricultural research, particularly within DSSAT's context, where water management plays a critical role in crop yield prediction. *Agricultural Systems*

Table 4 - Journal Contribution Zones Based on Bradford's Law

Zone	No. of Journals	No. of Documents	Percentage
Zone 1	7	132	35.87
Zone 2	25	115	31.25
Zone 3	99	121	32.88
Total	131	368	100

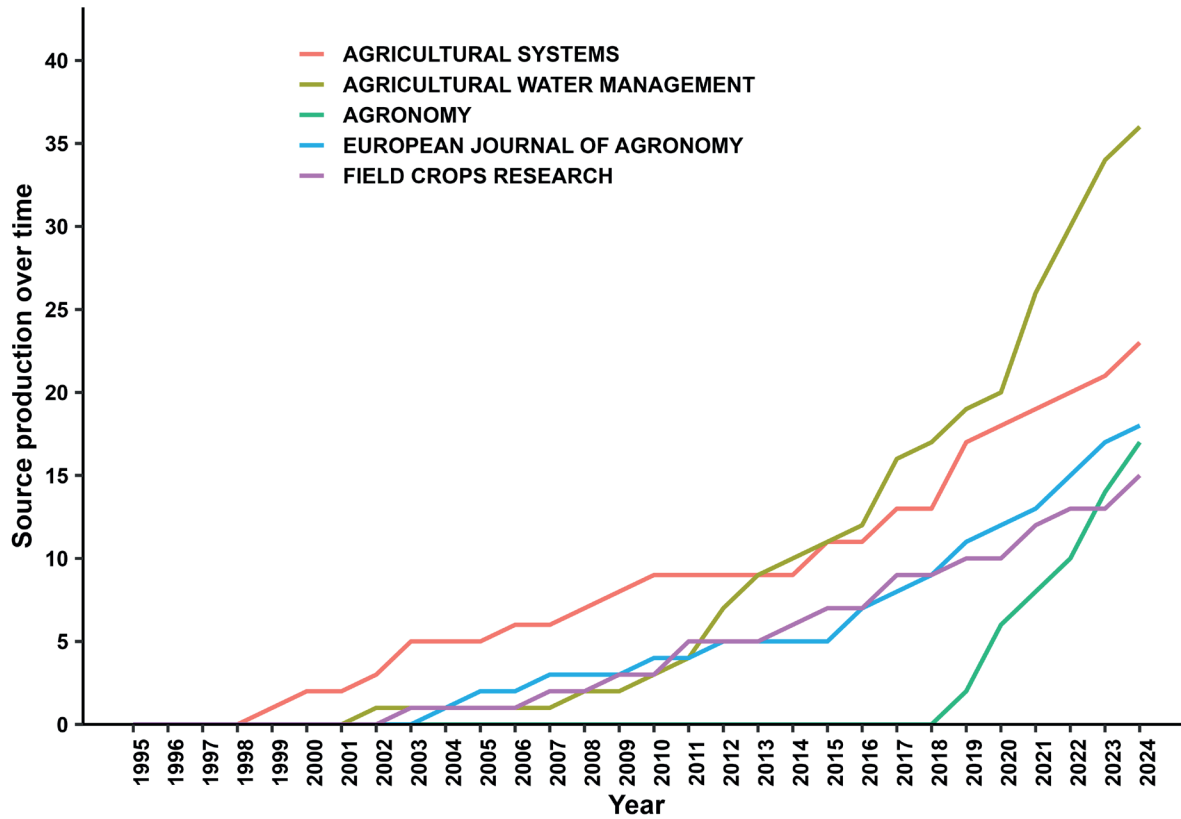


Fig. 3 - (b) Journal publication trends over time

25 and 2,591 citations, reflecting his significant influence in the field. Jones JW follows with 17 articles, an H-index of 16 and 1,134 citations, highlighting his ongoing academic impact. Yang JY (11 articles, H-index:

10) and Drury CF (10 articles, H-index: 9) have made notable contributions, though their citation impact (756 and 654 citations, respectively) is lower. Authors like Ma L and Ahuja LR (11 articles each) evinced moderate citation influence, with 689 and 645 citations. Boote KJ and Gowda PH (9 articles each) showed specialized contributions, with Gowda's research obtaining 248 citations. He, P and Araya A (8 articles each) have emerging impacts, with Araya A showing a higher M-index of 0.636, indicating consistent recent growth. Overall, these authors demonstrated varying levels of contribution, with Hoogenboom G leading in both the output and citation metrics, underscoring the critical role of these researchers in advancing DSSAT-based Maize yield prediction.

Table 6 - Author productivity through Lotka's law

Documents written	No. of Authors	Per cent of Authors
1	1,004	73.28
2	224	16.35
3	72	5.26
4	24	1.75
5	17	1.24
6	14	1.02
7	5	0.36
8	3	0.22
9	2	0.15
10	1	0.07
11	2	0.15
17	1	0.07
48	1	0.07

Author Productivity through Lotka's Law

Lotka's Law states that a small percentage of authors contribute many publications, while many authors contribute relatively few publications (Kushairi and Ahmi, 2021; Kalaimathi et al., 2024). The findings confirmed that a significant portion of authors (73.28%) contributed only one document, reflecting the "long tail" distribution where many authors were less productive. Also, fewer authors made more substantial contribu-

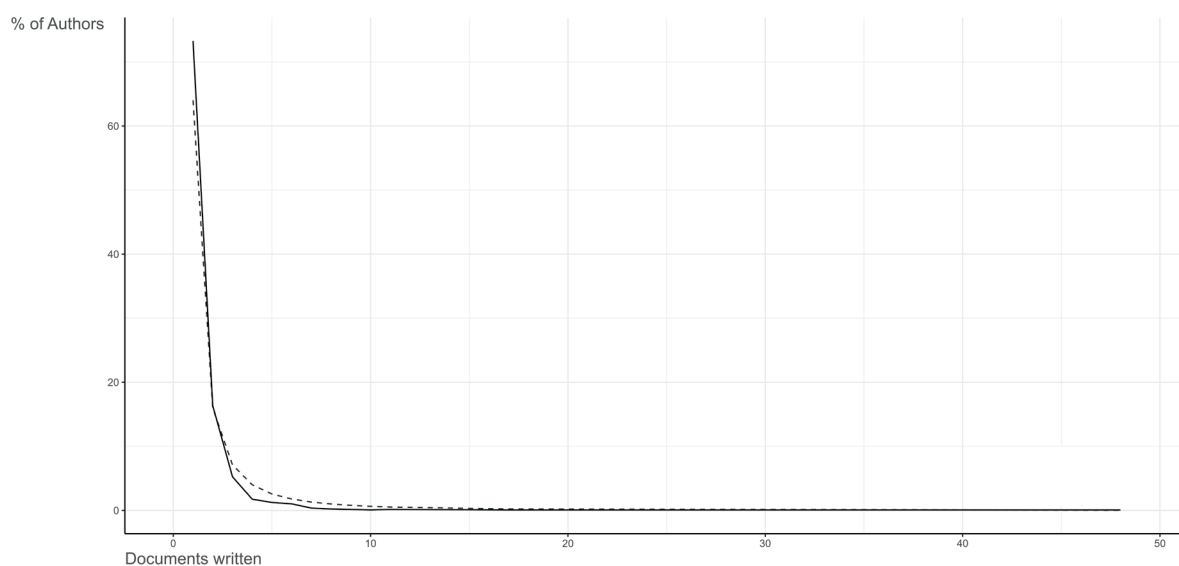


Fig. 4 - (a) Author Productivity through Lotka's Law

tions, with 16.35% contributing two documents, 5.26% contributing three documents and even few authors contributing more, such as one author producing 48 documents. This pattern aligned with Lotka's Law, which predicts that the number of authors producing a given number of documents follows a highly skewed distribution. The dashed line in Fig. 4a represents the expected distribution based on Lotka's Law, providing a visual comparison of actual productivity versus the predicted distribution. The data in Table 6 further confirms the distribution of productivity, emphasizing the concentration of output within a small subset of prolific authors and the large number of authors with minimal

contributions to the field.

Authors' Production over Time

Fig. 4b provides a lucid view of how authors' productivity and citation impact have evolved, highlighting key contributors and trends in Maize yield prediction research using DSSAT. The bubble size represents the number of articles published by each author annually, with larger bubbles indicating higher productivity. Authors like Hoogenboom G and Jones JW had consistent research publication output over time, revealing their significant role in the field. The colour intensity of each bubble reflects citation counts, with darker shades in-

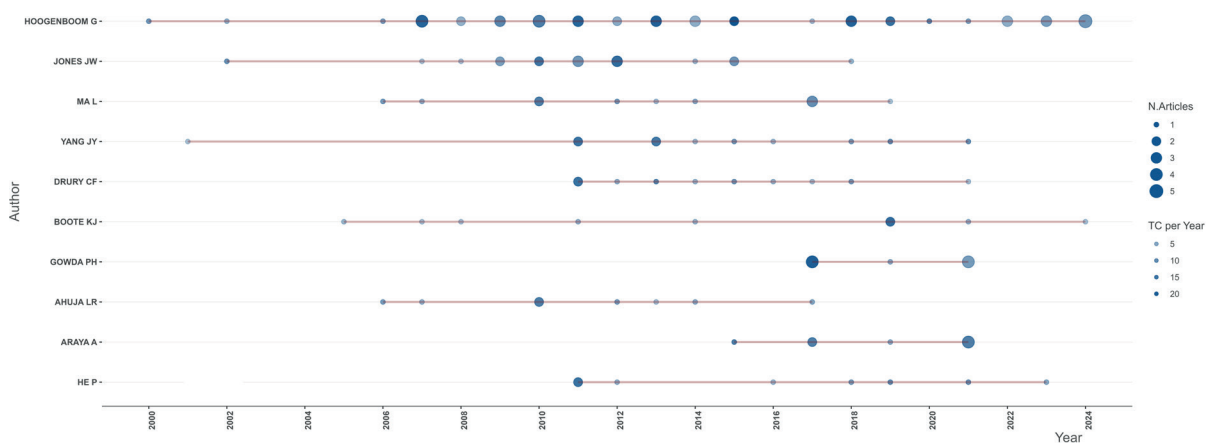


Fig. 4 - (b) Authors' production over time

Table 7 - Top Institutions Contributing to Maize Yield Prediction Using DSSAT

Institutions	Articles
University of Florida	93
Northwest AANDF University	57
Institute of Agricultural Resources and Regional Planning	36
Kansas State University	36
Fort Collins	31
Bahauddin Zakariya University	30
Michigan State University	27
University of Connecticut	26
Tamil Nadu Agricultural University	24
China Agricultural University	23

dicating higher impact. For example, Jones JW’s work has garnered increasing citations, particularly in recent years. The horizontal lines represent the authors’ research timelines, with longer lines signifying sustained contributions (articles), such as those from Hoogenboom G, whose work spans several decades. In contrast, authors like Araya A and He P have shorter timelines, reflecting more recent or intermittent contributions. Additionally, the distribution of bubbles shows varying publication patterns, with some authors like Yang JY publishing more in specific years, while others like Drury CF have more sporadic output.

Most relevant Institutions and publication trends over time

Table 7 provides the list of the top 10 institutions that contributed to Maize yield prediction research using DSSAT. The University of Florida leads with 93 articles, indicating its major influence in this field, followed by Northwest AANDF University with 57 articles. Both the institutions are pivotal in advancing agricultural modelling. The Institute of Agricultural Resources and Regional Planning and Kansas State University, each with 36 articles, contribute significantly to agricultural resource management and regional planning in crop yield prediction. Other notable institutes include Fort Collins (31 articles), Bahauddin Zakariya University (30 articles) and Michigan State University (27 articles), reflecting their strong academic output in crop modelling and sustainable farming practices. The University of Connecticut (26 articles), Tamil Nadu Agricultural University (24 articles) and China Agricultural University (23 articles) represent global research efforts, underscoring the international interest in using DSSAT to predict maize yield. These institutions collectively shape the landscape of crop yield prediction, with diverse geographic contributions driving global advancements in agricultural science.

Fig 5. illustrates the publication trends of key institutions in Maize yield prediction research using DSSAT over time. University of Florida demonstrates a consistent growth, increasing from zero articles in the early 2000s to 93 by 2024, with a remarkable rise from 2007

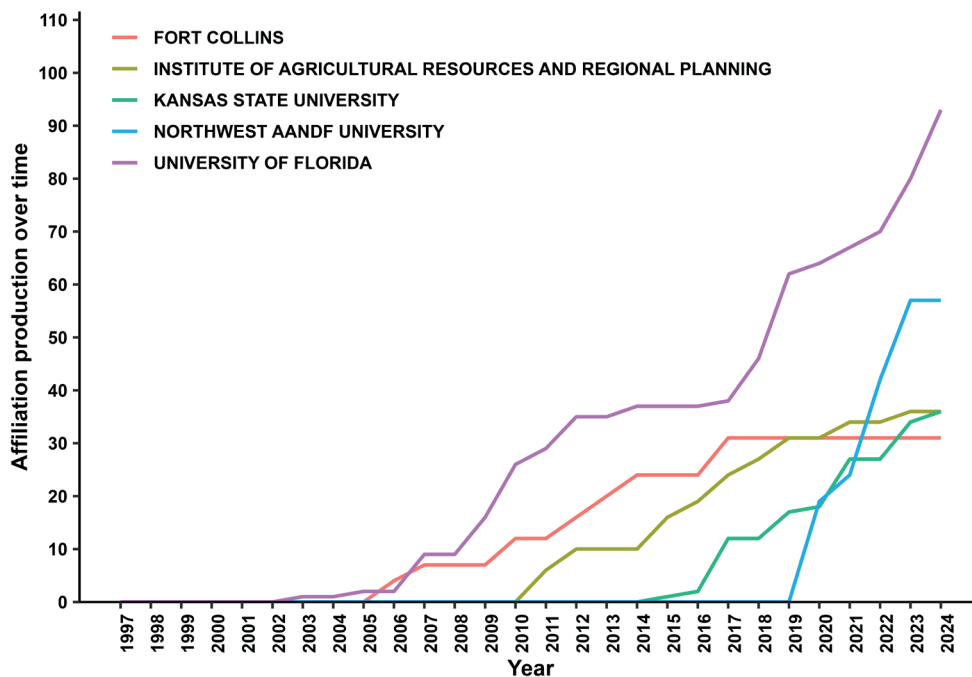


Fig. 5 - Affiliation production over time

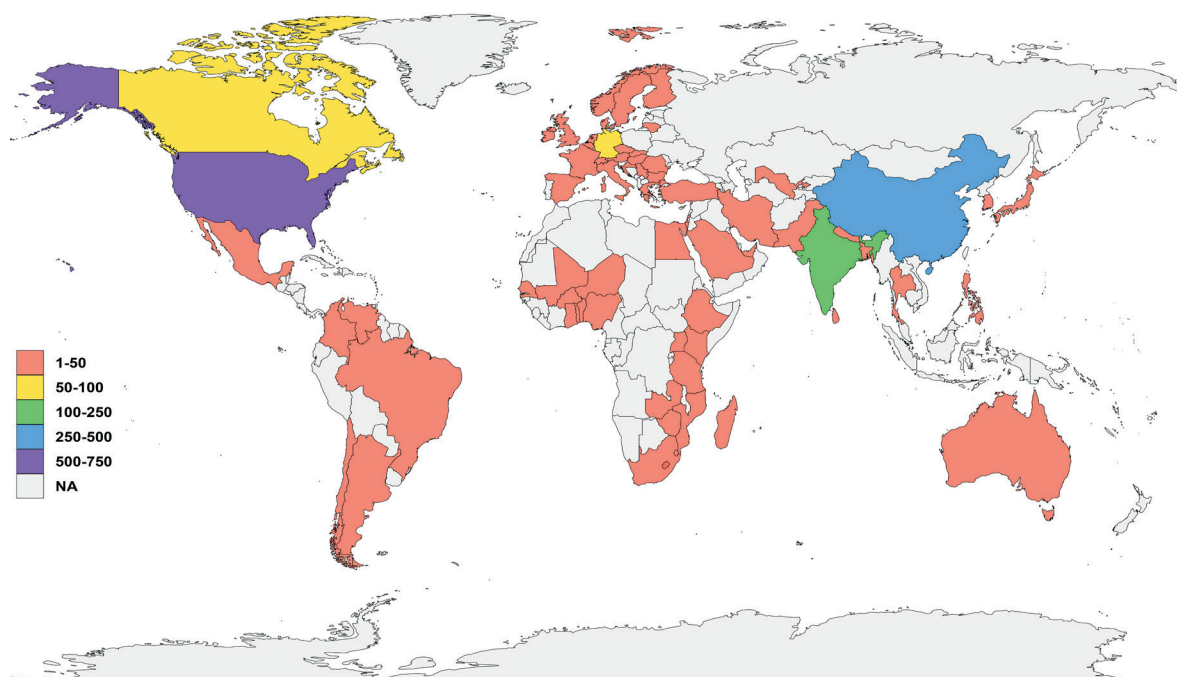


Fig. 6 - (a) Countries' scientific production

onwards. Fort Collins also had a steady growth, reaching 31 articles by 2024. The Institute of Agricultural Resources and Regional Planning started publishing in 2011 and increased to 36 articles by 2024, reflecting its growing involvement in Maize yield research. Kansas State University showed a gradual growth from 2015, reaching 36 articles by 2024. Northwest AANDF University experienced a peak in productivity from 2020, publishing 57 articles by 2024. These trends highlight the expanding role of these institutions in Maize yield prediction, with the University of Florida maintaining sustained output and others like Northwest AANDF

Table 8 - Top Countries Contributing to Maize Yield Prediction Using DSSAT

Country	Articles
USA	661
China	371
India	156
Canada	98
Germany	94
Italy	50
Brazil	46
Pakistan	44
Ghana	38
Ethiopia	35

University have had recent productivity growth. These trends reflect the dynamic and evolving nature of agricultural research, with institutions progressively expanding their research capacity and focus on Maize yield prediction using DSSAT.

Countries' scientific production and publication trends over time

The global contribution to Maize yield prediction research using DSSAT reflects a growing interest in agricultural modelling across various regions (Fig. 6a). The USA leads by a significant margin with 661 articles, as shown in Table 8, demonstrating a sustained research efforts and leadership in this field. China, with 371 articles, reflected its rapid growth in agricultural research, particularly after 2015. India also played an essential role, increasing its output from zero publications in the early years to 156 by 2024, highlighting the country's growing focus on agricultural technologies. Other countries like Canada (98 articles), Germany (94 articles) and Italy (50 articles) have made considerable contributions, enhancing global knowledge on Maize yield prediction. Brazil (46 articles) and Pakistan (44 articles) are also noteworthy contributors, underlining the importance of Maize production in these regions. Ghana (38 articles) and Ethiopia (35 articles) round out the top 10, emphasizing the increasing interest in Maize yield prediction research in Africa.

Fig. 6b presents the publication trends from 1995 to 2024, showing a significant rise in output, particularly

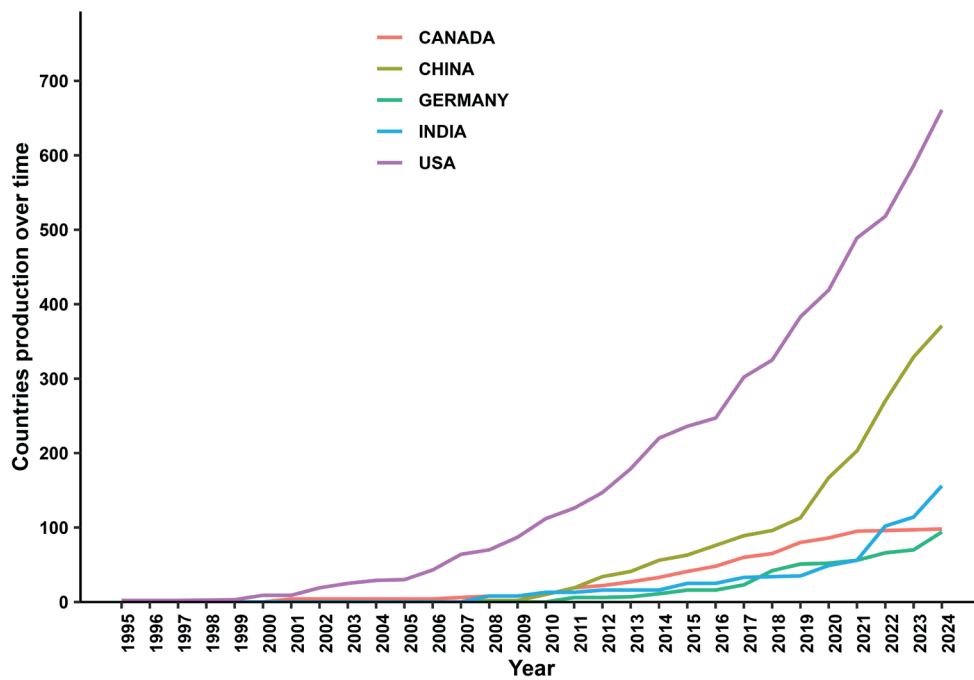


Fig. 6 - (b) Countries' production over time

in the USA, which has increased from just 2 articles in 1995 to 661 in 2024. China has experienced rapid growth, particularly after 2015, with 371 articles by 2024. India has steadily increased its publications, reaching 156 by 2024. Countries such as Canada and Germany have also shown continuous growth, reflecting the expanding global collaboration in utilizing DSSAT for crop modelling, contributing to advancements in food security and agricultural sustainability worldwide.

Collaborative pattern of corresponding author's countries

The top countries that contributed primarily to Maize yield prediction research using DSSAT are primarily led by the USA (101 articles, 27.4%), which has a strong emphasis on single-country publications (SCP) with 72 articles and a smaller proportion of multiple-country publications (MCP) for 29 articles. China followed with 57 articles (15.5%) and a high MCP percentage (38.6%), signifying its increasing international collaboration. India (17 articles, 4.6%) showed a balance between SCP and MCP, with 14 SCP articles and only 3 MCP articles, indicating less international collaboration compared to the USA and China. Germany and South Africa had a significant proportion of their publications as MCP (71.4%), suggesting an increasing trend toward international collaboration. Ghana stands out with 83.3% of its publications being MCP, signalling its engagement in collaborative research on a global scale. Other countries such as Canada, Brazil, Iran and Ethiopia show varied

collaboration patterns, contributing to the expanding global research network in Maize yield prediction (Fig. 7).

Citation profile of top countries

Table 9 provides insights into the citation profiles of leading countries in Maize yield prediction research using DSSAT. The USA is the dominant contributor, with 3,860 citations and an average of 38.20 citations per article. This highlighted the country's sustained and impactful research in the academic community. China followed the USA with 1,354 total citations and an

Table 9 - Citation profile of top countries contributing to Maize Yield Prediction Using DSSAT

Country	Total Citations	Average Article Citations
USA	3860	38.20
China	1354	23.80
Canada	539	41.50
Brazil	439	39.90
Iran	313	31.30
Spain	267	44.50
Germany	252	18.00
Bulgaria	239	79.70
Georgia	210	42.00
Ethiopia	181	25.90

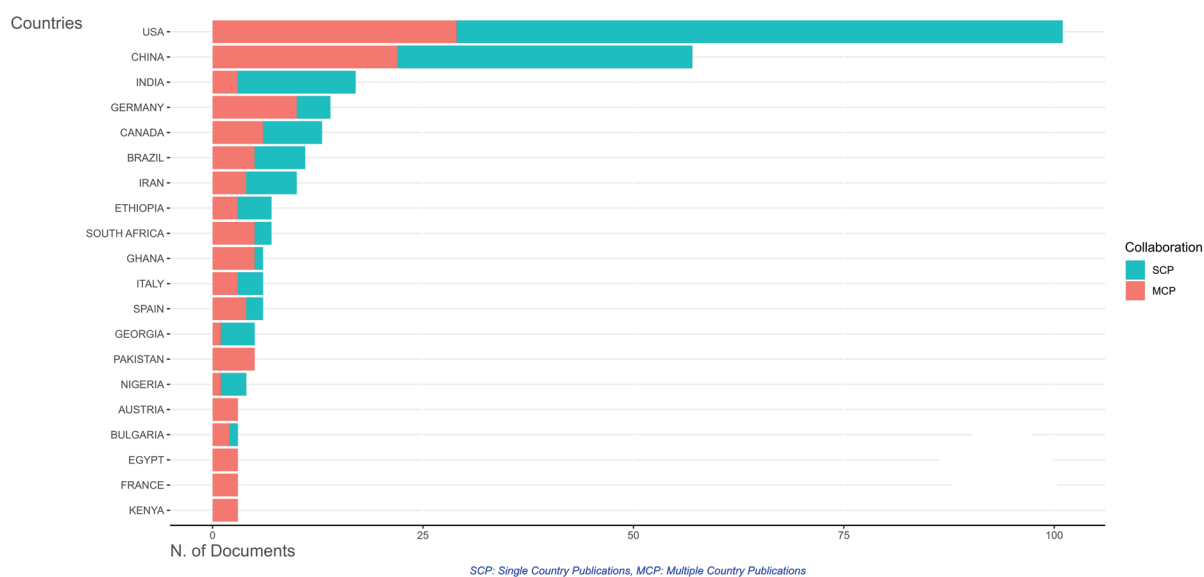


Fig. 7 - Collaborative pattern of corresponding author's contribution

average of 23.80 citations per article. While the total citation count is substantial, the lower average citation per article suggested its publications might not have as broad or intense academic influence as those from the USA. Canada and Brazil showed a relatively high average citation rate, with Canada leading at 41.50 and Brazil at 39.90. Despite having fewer total citations (539 and 439), their higher average citations reflect that their research, although less frequent, was highly impactful within the community of Maize yield prediction. This could be attributed to the fact that targeted contributions in specific research areas are cited more and frequently by the academic community. Spain performed well with an average of 44.50 citations per article, indicating that the publications from Spain were highly

influential. However, Spain's total citation count (267) is relatively low compared to the USA and China, suggesting fewer but high-impact publications in this research area. Countries like Bulgaria (79.70 average citations), Georgia (42.00) and Iran (31.30) have a higher average citation rate per article, highlighting the concentrated contributions that are highly valued by the academic community. Bulgaria had an exceptional average of 79.70 citations, which may indicate highly specialised and impactful research in Maize yield prediction. Finally, Ethiopia, with a total of 181 citations and an average of 25.90 citations per article, contributes fewer publications but still plays a notable role in the field. The relatively lower citation count indicates that while the research output is smaller, the individual articles

Table 10 - Citation Profile of Key Documents on Maize Yield Prediction Using DSSAT

Paper	Journal	DOI	Total Citations	Citations per Year	Normalized Total Citations
Ines et al. (2013)	Remote Sensing of Environment	10.1016/j.rse.2013.07.018	343	26.38	3.76
Soler et al. (2007)	European Journal of Agronomy	10.1016/j.eja.2007.03.002	228	12.00	3.82
Tubiello et al. (2002)	Climate Research	10.3354/cr020259	221	9.21	2.05
Alexandrov and Hooogenboom (2000)	Agricultural and Forest Meteorology	10.1016/S0168-1923(00)00166-0	213	8.19	1.65
He et al. (2010)	Agricultural Systems	10.1016/j.agsy.2010.01.006	190	11.88	3.27
Fang et al. (2010)	Agricultural Water Management	10.1016/j.agwat.2009.02.012	176	11.00	3.03
Liu et al. (2013)	Agricultural Water Management	10.1016/j.agwat.2013.03.001	152	11.69	1.67
Araya et al. (2015)	Agricultural and Forest Meteorology	10.1016/j.agrformet.2015.08.259	150	13.64	3.79
Liu et al. (2011)	Nutrient Cycling in Agroecosystems	10.1007/s10705-010-9396-y	142	9.47	2.72
Ma et al. (2006)	Agricultural Systems	10.1016/j.agsy.2005.02.001	138	6.90	2.17

still receive substantial attention. In summary, the data reflect the varying contributions and citation impacts from different countries. The USA had the highest total citations and the overall volume of publications, while countries like Bulgaria and Spain demonstrated that high citation impact does not always correlate with the number of publications. This highlights the diversity in research output, with some countries focusing on fewer but highly influential articles, while others maintain a more consistent and broader output.

Global citation analysis of top papers related to maize yield estimation using DSSAT

The top 10 most globally cited papers on maize yield prediction using the Decision Support System for Agrotechnology Transfer (DSSAT) model had made a substantial contribution to the advancement of crop modelling (Table 10). Ines *et al.* (2013) (*Remote Sensing of Environment*) led with 343 citations, focusing on the integration of remote sensing data into crop models to enhance predictive accuracy. This study has been highly influential, with a normalized total citation rate of 3.76, demonstrating its continued relevance. Similarly, Soler *et al.* (2007) (*European Journal of Agronomy*) obtained 228 citations, emphasizing the role of agronomic practices in optimizing maize yield predictions. This paper has been instrumental in advancing the integration of variables such as irrigation and nutrient management within DSSAT, providing crucial insights for precision agriculture.

Other key works in this field, such as those by Tubiello *et al.* (2002) in *Climate Research* and Alexandrov and Hoogenboom (2000) in *Agricultural and Forest Meteorology*, explore the impact of climate factors on maize yields, with 221 and 213 citations, respectively. These papers helped shape the understanding of how climate variability and change affect crop productivity, making them critical in developing adaptive management strategies for crop modelling. Similarly, papers by He *et al.* (2010), Fang *et al.* (2010) and Liu *et al.* (2013) address various environmental factors such as water management and nutrient cycling, further refining the predictive capabilities of DSSAT. Collectively, these highly cited documents reflect the interdisciplinary nature of maize yield prediction, integrating remote sensing, climate data, agronomy and nutrient management to enhance crop modelling accuracy and support food security efforts in view of environmental challenges.

Reference Publication Year Spectroscopy (RPYS)

Reference Publication Years Spectroscopy (RPYS) is an analytical method employed to identify the historical origins and major discoveries within research fields, offering a timeline of significant developments (Baek and Doleck, 2020). The analysis of the cited references over time, as depicted in Fig. 8, reveals distinct trends in the Maize yield prediction research using DSSAT, aligning with the fluctuations in the number of citations per year. The black line in the figure represents the number of cited references per year, showing a sharp increase in ci-

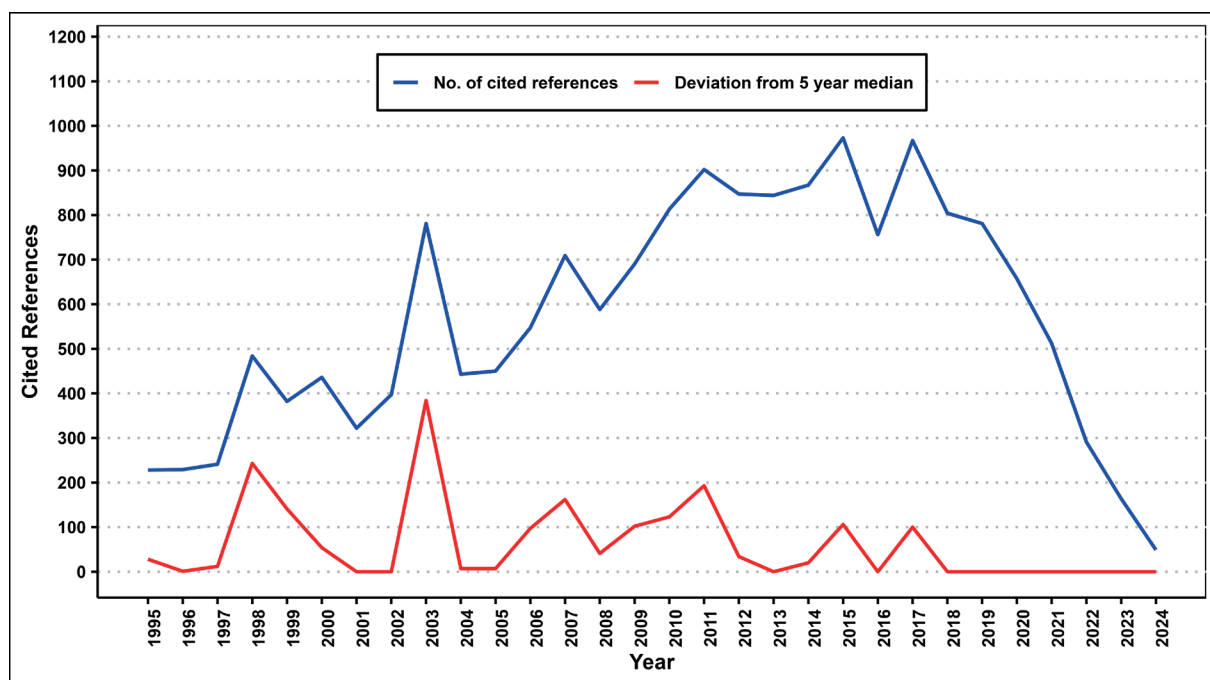


Fig. 8 - Reference Publication Year Spectroscopy (RPYS)

rent research. Heatmap (Fig. 9b) indicates how the frequency of each term related to DSSAT, maize yield and related topics have evolved from 1995 to 2024. The increasing interest in CERES-MAIZE, adaptation and evapotranspiration emphasizes the need for comprehensive, integrated approaches to address the challenges of modern agriculture. As such, DSSAT remains a critical tool for predicting maize yields and adapting agricultural practices to the changing climate, reinforcing the growing trend of research focused on sustainable crop management and climate-resilient agriculture.

Thematic maps

The thematic map (Fig. 9c) provides a strategic overview of the conceptual structure of maize yield prediction research using DSSAT by mapping themes according to their centrality (relevance) and density (development). The analysis revealed that DSSAT, maize and crop model occupy the basic themes quadrant, indicating their foundational yet underdeveloped status across multiple studies, signalling strong relevance with scope for intense research. Motor themes such as tillage, agricultural management, nitrogen balance and nitrogen management reflect well-established and highly interconnected research foci, underscoring the critical role of field and nutrient management in yield

optimization. In contrast, niche themes like cropgro, fertilizer management, yield gaps and climate models demonstrate high specialization but limited interdisciplinary integration. Meanwhile, the emerging or declining quadrant includes themes such as planting window, carbon dioxide and uncertainty, suggesting potential research areas requiring renewed focus. Overall, the thematic structure highlighted the centrality of DSSAT and maize as core components of the research domain, while emphasizing the continued evolution of management-focused and climate-related themes. The distribution also suggested a growing emphasis on model inter-comparison, yield potential estimation and integration of economic parameters, which are key for enhancing the practical utility of DSSAT in maize yield prediction.

Collaboration within authors, institutions and countries

Fig. 10a explains the collaboration network among authors, where each node represents an author and the edges (lines) between them show their collaborative relationships. Central nodes (e.g., Hoogenboom G) are larger and more connected, indicating that these authors are key figures in the network, with broad and significant collaborations. The network also features clusters of authors, colour-coded to suggest groups

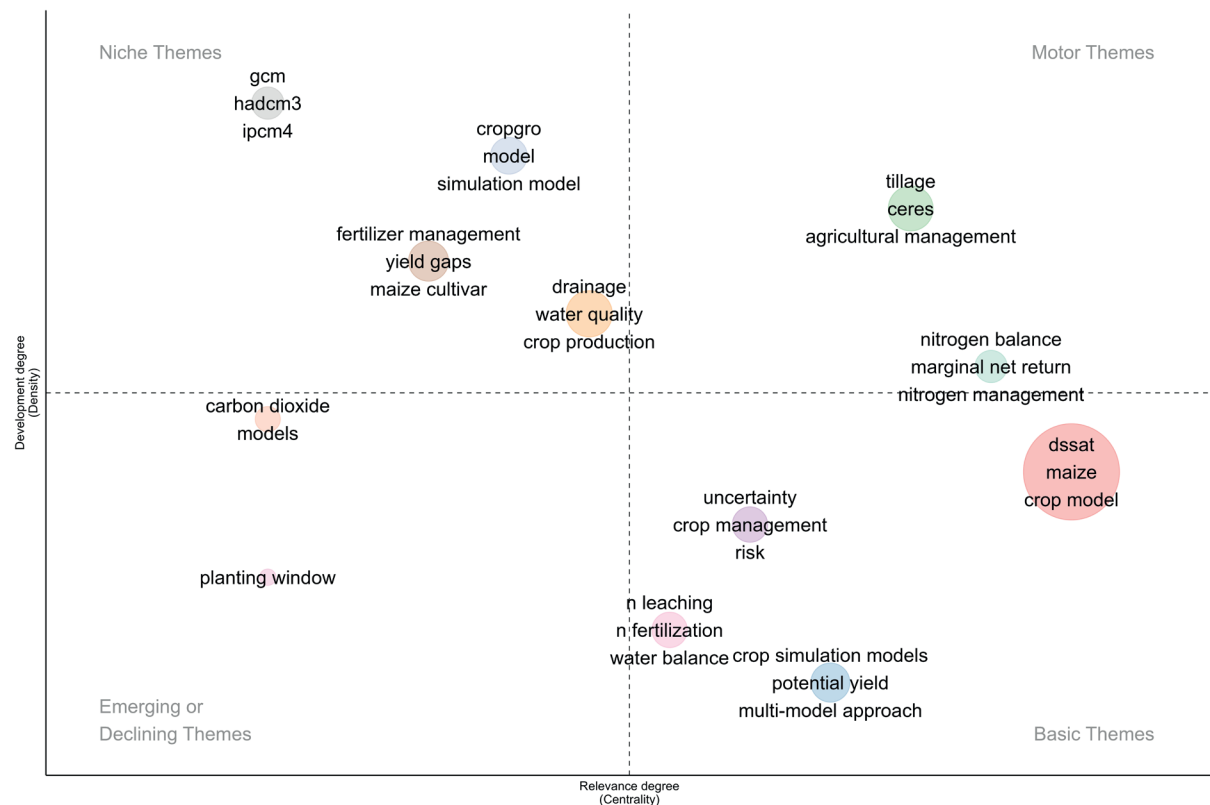


Fig. 9 - (c) Thematic map of the author's keywords

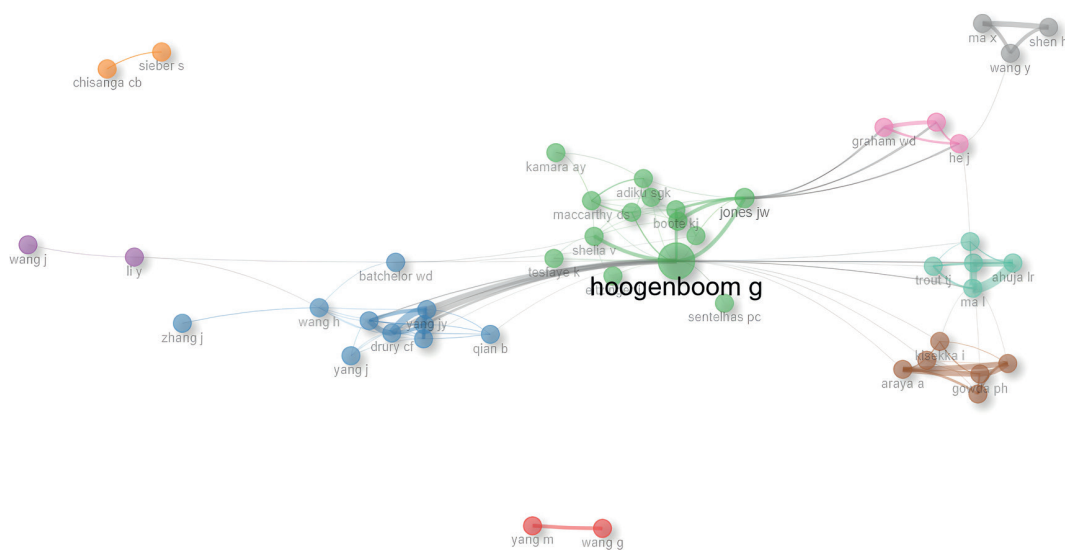


Fig. 10 - (a) Authors' collaboration network

that frequently collaborate, potentially indicating shared research topics, institutions, or geographic regions. Stronger, thicker lines between nodes highlight more frequent or influential collaborations, with central authors often contributing to impactful research. Authors with more connections are likely involved in high-impact research related to maize yield estimation with DSSAT.

Fig. 10b represents a collaboration network of universities and research institutions, where each node corresponds to a specific institution or university and the ed-

ges (lines) connecting them signifies their collaborative relationships. The size of the nodes, along with the clustering of different colours, suggests the intensity and frequency of collaborations. The University of Florida, as a central node, is highly connected with multiple institutions, indicating its pivotal role in the collaboration network. The coloured clusters reflect groups of institutions that frequently collaborate, often representing geographical or research topic groupings. The image illustrates how global collaboration networks facilitate knowledge exchange, with prominent institutions at the centre of these collaborations, contributing to im-

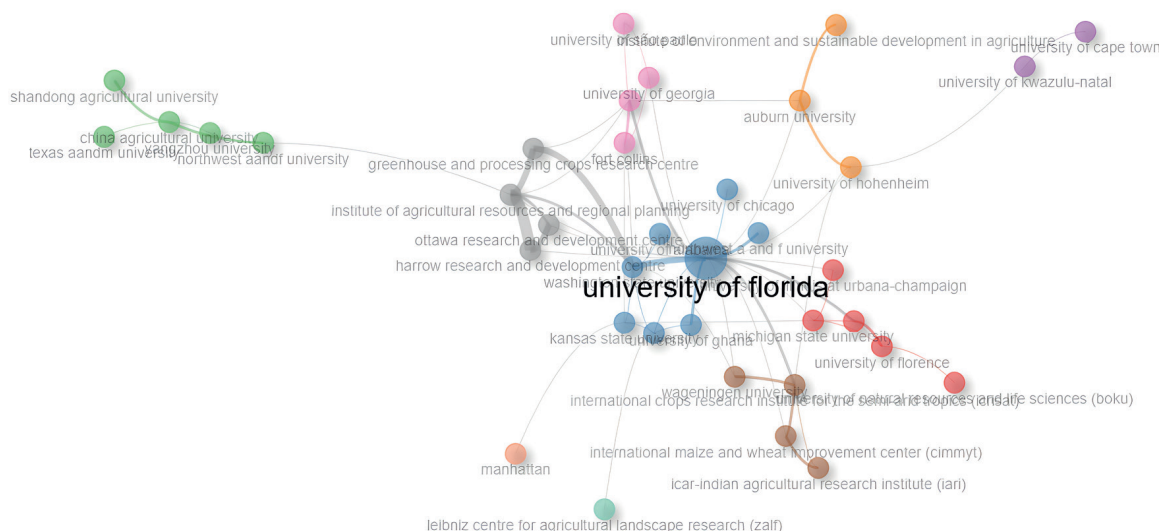


Fig. 10 - (b) Institutions' collaboration network

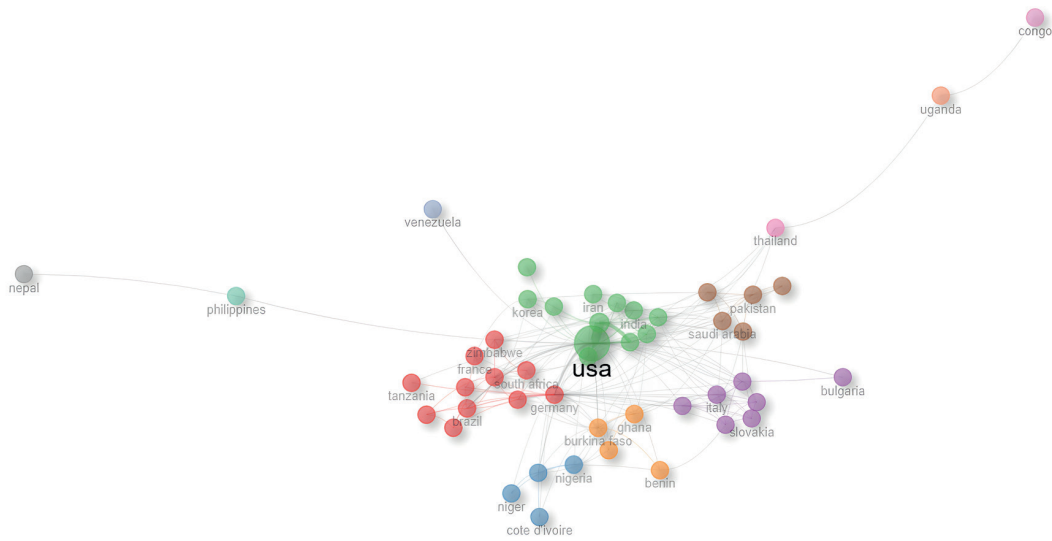


Fig. 10 - (c) Countries' collaboration network

pactful research on maize yield estimation with DSSAT. The collaboration networks presented in Fig. 10c and Fig. 10d illustrate the extensive global involvement in maize yield estimation using DSSAT, with the United States, India, South Africa, Brazil and Iran forming key nodes in this research network. These nations are central to the development and application of DSSAT models, contributing to simulating crop growth and improving maize yield predictions based on factors such as climate, soil types and management practices. The dense interconnections between these countries

highlight their active participation in validating and refining DSSAT models, adapting the tool to local conditions and addressing shared agricultural challenges, such as climate change, food security and precision agriculture. Countries in Asia, Africa and Europe are also strongly represented, reflecting a collaborative effort to improve global maize productivity through research and technological advancements. These global partnerships emphasize the importance of international cooperation in ensuring the effectiveness of DSSAT for accurate yield forecasting and the advancement of sustainable agricultural practices worldwide.

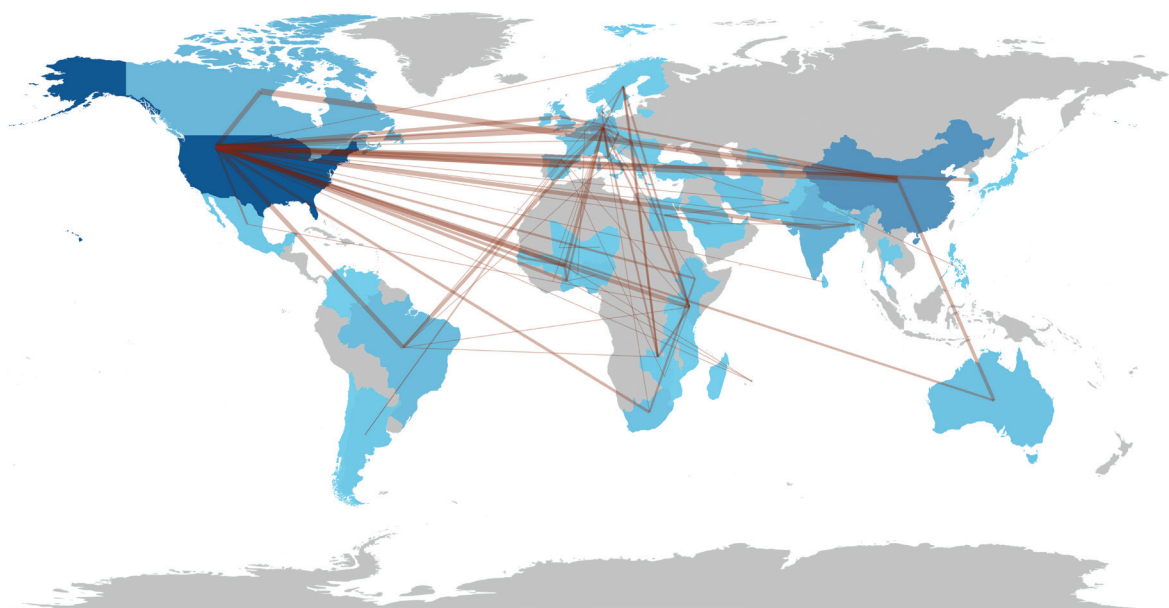


Fig. 10 - (d) Countries' collaboration Map

Conclusion

This bibliometric analysis provides a comprehensive overview of the current state of research on maize yield prediction using the DSSAT, offering a deeper understanding of the trends and key contributors. This analysis revealed a steady increase in both the volume and impact of publications from 1995 to 2024, reflecting the expanding academic interest and global relevance of the DSSAT in addressing challenges in crop management and food security. The collaborative nature of the field is evident, with a substantial proportion of research being co-authored internationally, particularly by leading institutions in the USA, China and India. The key themes identified include the integration of climate change, crop modelling and water management strategies, all of which are critical for optimising maize yield predictions under varying environmental conditions. The analysis further underscores the shifting focus of research towards specialised areas, indicating a broader trend towards improving the precision and adaptability of DSSAT in predicting maize yields, especially in the context of global climate variability. Thus, DSSAT remains a cornerstone tool for agricultural modelling and ongoing research continues to refine its capabilities, ensuring its vital role in promoting sustainable agricultural practices. Future research should explore more localised adaptations of the model, integrating economic factors and broader climatic scenarios to enhance its predictive accuracy, thereby contributing to global food security and agricultural sustainability.

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