

# Green IT in Agriculture: A Bibliometric and Theoretical Analysis of Digital Agriculture Research

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## Green IT in Agriculture: A Bibliometric and Theoretical Analysis of Digital Agriculture Research

### Abstract :

This study provides a bibliometric and conceptual analysis of Green Information Technology (Green IT) management in the agricultural sector. Despite the growing interest in sustainable digital technologies, existing research remains fragmented and lacks a clear management-oriented perspective. Literature is largely dominated by technological approaches, with limited attention to managerial and user-centered dimensions. This research adopts a positivist epistemological stance, consistent with the objective of mapping and structuring a scientific field based on bibliometric data. It aims to identify the main research themes, clarify the terminology used in the field, and highlight key gaps related to the adoption, acceptance, and actual use of Green IT in agriculture.

Using a dataset of 5,984 publications extracted from the Scopus database, a co-word analysis was conducted with VOSviewer to map the intellectual structure of the field. The findings reveal four dominant thematic clusters: precision agriculture, remote sensing, Internet of Things (IoT), and irrigation systems, reflecting a strong technological orientation. The results also show significant conceptual fragmentation, with terms such as smart agriculture, digital agriculture, and climate-smart agriculture being widely used, while “Green IT” itself remains marginal in the literature.

This study relies exclusively on secondary data from Scopus and a bibliometric co-word analysis, which limits causal interpretation of the findings and does not capture the qualitative and contextual dimensions of the studied phenomena. Nevertheless, it contributes to clarifying the conceptual landscape of Green IT in agriculture and proposes a research agenda integrating technological, organizational, and sustainability perspectives.

**Keywords:** Green IT management, adoption, Sustainable agriculture, Information systems, Bibliometric analysis, Innovation.

**Classification JEL :** O33, M15, Q16, O13, Q55.

**Paper type:** Empirical Research

### Résumé :

Cette étude propose une analyse bibliométrique et conceptuelle de la gestion des technologies de l'information vertes (Green Information Technology – Green IT) dans le secteur agricole. Malgré l'intérêt croissant pour les technologies numériques durables, les travaux existants demeurent fragmentés et ne présentent pas de positionnement clairement stabilisé en sciences de gestion. La littérature est principalement dominée par des approches technocentrées, accordant une attention limitée aux dimensions managériales, organisationnelles et à l'acceptation des utilisateurs. Cette recherche adopte une posture épistémologique positiviste, cohérente avec un objectif de cartographie et de structuration d'un champ scientifique à partir de données bibliométriques. Elle vise à identifier les principaux thèmes de recherche, à clarifier les terminologies mobilisées et à mettre en évidence les lacunes liées à l'adoption et à l'usage des Green IT en agriculture.

À partir d'un corpus de 5 984 publications issues de Scopus, une analyse de cooccurrence des mots-clés a été réalisée à l'aide de VOSviewer afin de cartographier la structure intellectuelle du domaine. Les résultats mettent en évidence quatre clusters dominants centrés sur l'agriculture de précision, la télédétection, l'Internet des objets (IoT) et les systèmes d'irrigation, traduisant une forte orientation technologique du champ. Ils révèlent également une fragmentation conceptuelle autour de notions telles que l'agriculture intelligente, l'agriculture numérique, et climate-smart agriculture. Par ailleurs, le terme Green IT apparaît marginalement mobilisé, suggérant un décalage entre le cadre conceptuel et les objets étudiés.

Cette étude repose sur des données secondaires issues de Scopus et sur une analyse bibliométrique de cooccurrence, ce qui limite toute interprétation causale. Elle contribue néanmoins à clarifier la structuration conceptuelle du champ et propose un agenda de recherche intégrant les dimensions technologiques, organisationnelles et de durabilité.

**Mots clés :** Management Green IT, adoption, agriculture durable, systèmes d'Information, analyse bibliométrique, Innovation.

**JEL Classification :** O33, M15, Q16, O13, Q55.

**Type du papier :** Recherche empirique

## 1. Introduction

The agricultural sector plays a critical role in ensuring global food security while simultaneously exerting significant pressure on natural resources through intensive water use, land degradation, and greenhouse gas emissions. In this context, the transition toward sustainable agricultural systems has become a major global priority. The increasing need to reconcile productivity gains with environmental preservation has accelerated the diffusion of digital technologies in agriculture. Among these innovations, Green Information Technology (Green IT) has emerged as a promising approach to support sustainability by enabling more efficient resource use and environmentally responsible decision-making.

Green IT is defined in this study as the set of practices, strategies, and digital technologies designed to minimize the environmental impact of information systems throughout their lifecycle, including design, use, and disposal phases. In agriculture, it encompasses technologies such as farm management information systems, remote sensing tools, geographic information systems (GIS), and Internet of Things (IoT)-based solutions, which collectively contribute to improving resource efficiency and reducing environmental footprints.

Despite increasing academic attention, the literature on digital technologies in agriculture remains fragmented and predominantly technology oriented. Existing studies tend to emphasize technical performance, while managerial, organizational, and behavioral dimensions remain underexplored. In particular, the distinctions between technology adoption, acceptance, and actual use are often blurred. Moreover, conceptual ambiguity persists due to the interchangeable use of terms such as precision agriculture, smart agriculture, digital agriculture, and climate-smart agriculture, which complicates the positioning of Green IT within the broader agricultural innovation landscape.

Previous bibliometric studies have examined related domains of agricultural digital transformation. For instance, Bertoglio et al. (2021) analyzed research trends in smart agriculture technologies, while Luckyardi et al. (2022) investigated the evolution of digital agriculture research. However, these studies primarily focus on technological or thematic evolution without explicitly addressing Green IT as an integrative concept linking information systems management and environmental sustainability. This highlights the need for a dedicated bibliometric synthesis focused specifically on Green IT in agriculture.

Against this background, this study aims to provide a comprehensive bibliometric mapping of Green IT research in agriculture using Scopus data and co-word analysis techniques. The study is guided by the following central research question: ***How is the scientific literature on Green IT in agriculture structured, and what are its main intellectual, thematic, and evolutionary dynamics?***

This research is further guided by the following sub-questions: What are the main thematic areas and their evolution over time? What conceptual frameworks and terminologies structure the literature? How do issues related to adoption, acceptance, and use of Green IT appear in literature?

This study contributes to literature in three main ways. First, it provides a comprehensive mapping of the intellectual and thematic structure of Green IT research in agriculture. Second, it clarifies the conceptual positioning of Green IT within the broader field of agricultural digital transformation. Third, it develops a management-oriented interpretation of the literature by highlighting the fragmentation of research streams and the underexplored behavioral and organizational dimensions of technology implementation.

The remainder of this paper is organized as follows. The next section presents the theoretical background on Green IT and technology adoption. The methodology section describes the bibliometric approach and data collection process. The results section presents the main

findings, followed by a discussion of their implications. Finally, the paper concludes by outlining limitations and directions for future research.

## **2. Literature review**

### **2.1. Conceptual positioning of the study in agricultural digital transformation research**

In the information systems (IS) and sustainability literature, Green IT is increasingly considered as an environmental extension of digital transformation strategies. Rather than being limited to a set of technical practices, it is embedded within broader governance and organizational efforts aimed at improving resource efficiency and reducing environmental impacts associated with digital infrastructures.

In agriculture, Green IT is not studied as an isolated construct but is instead implicitly embedded within overlapping paradigms such as precision agriculture, smart agriculture, and digital agriculture. These paradigms emphasize the use of data-driven technologies yet often differ in their degree of integration between environmental sustainability objectives and information systems management perspectives. This conceptual overlap contributes to the fragmentation of the field and the absence of a unified analytical framework.

### **2.2. Critical comparison of technology adoption theories in IS literature**

Technology adoption in information systems has been extensively theorized through several dominant models, including the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), the Technology-Organization-Environment (TOE) framework, and the Diffusion of Innovation (DOI) theory.

The TAM framework (Davis, 1989) focuses on perceived usefulness and ease of use as determinants of behavioral intention. While foundational, it has been criticized for its limited consideration of contextual, organizational, and environmental influences, which are particularly relevant in agricultural settings.

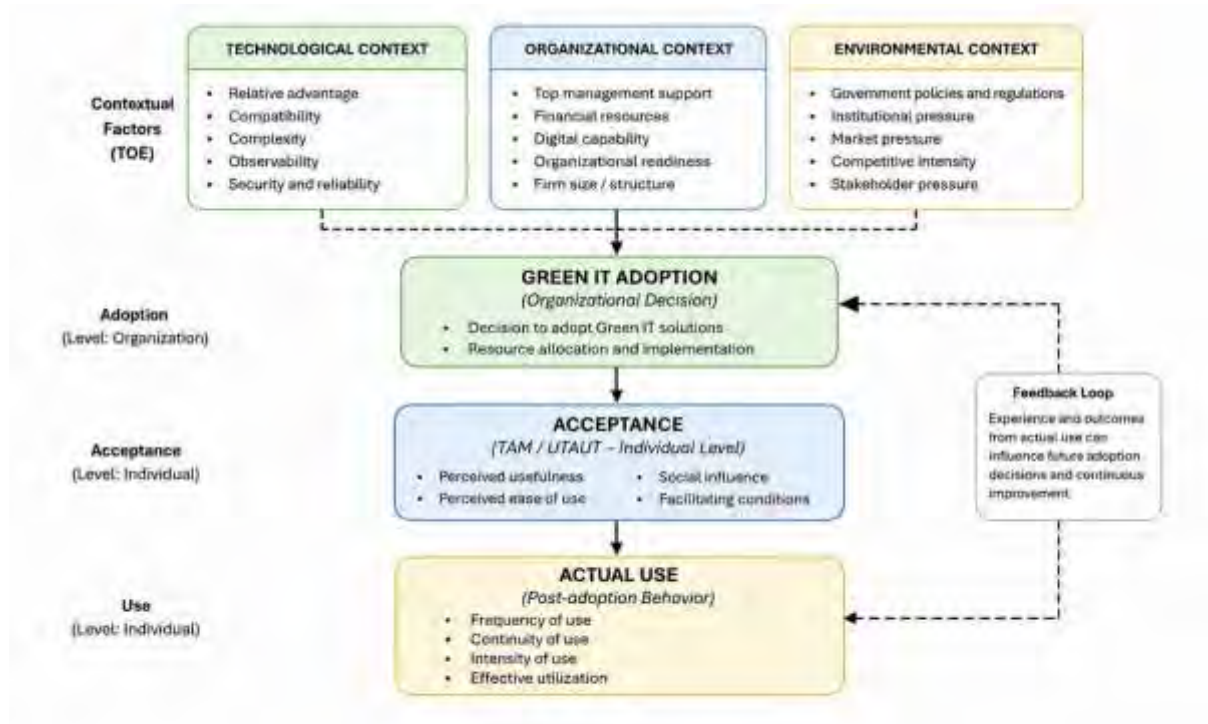
The UTAUT model (Venkatesh et al., 2003) extends TAM by incorporating social influence and facilitating conditions. However, its development in structured organizational environments in developed economies limits its explanatory capacity in agricultural systems characterized by infrastructural constraints and heterogeneous user profiles.

The TOE framework introduces a multi-level perspective by integrating technological, organizational, and environmental dimensions, making it more suitable for organizational adoption studies in agriculture. Nevertheless, it provides limited insight into individual behavioral mechanisms such as acceptance and continued usage.

The DOI theory (Rogers, 2003) conceptualizes adoption as a temporal diffusion process but remains insufficient in explaining post-adoption behavior and sustained use of digital technologies.

Collectively, these theories offer complementary insights but remain individually insufficient to fully explain Green IT-related adoption processes in agricultural contexts, particularly in heterogeneous and resource-constrained environments.

**Figure 1: Integrated conceptual framework of Green IT adoption, acceptance, and use in agriculture**



*Source: Authors' own elaboration based on the literature.*

### 2.3. Theoretical perspectives on technology adoption, acceptance, and use

A recurring conceptual limitation in the IS and agricultural technology literature concerns the lack of clear distinction between adoption, acceptance, and actual use.

Adoption refers to the decision to implement a technology at individual or organizational level, typically associated with innovation decision processes (Rogers, 2003). Acceptance refers to the cognitive and behavioral intention to use a technology, as theorized in TAM and UTAUT frameworks (Davis, 1989; Venkatesh et al., 2003). Actual use reflects the post-adoption phase, capturing the real utilization behavior over time, including frequency and continuity of use.

From a theoretical perspective, these constructs represent successive but distinct stages of the technology assimilation process. Adoption reflects the decision to acquire or implement a technological innovation (DOI; TOE), acceptance captures users' psychological readiness and behavioral intention to engage with the technology (TAM; UTAUT), whereas actual use refers to the effective utilization of the technology after implementation. Distinguishing these stages is particularly important in the context of Green IT, as successful organizational adoption does not necessarily guarantee user acceptance or sustained use. This distinction provides a useful analytical lens for interpreting the evolution of Green IT research in agriculture.

The conflation of these constructs in prior agricultural studies leads to measurement inconsistencies and limits the understanding of the full technology lifecycle. A clear conceptual separation is therefore necessary to better analyze Green IT diffusion and impact.

### 2.4. Contextual constraints in agricultural technology adoption in emerging economies

Although mainstream IS adoption theories provide valuable explanatory frameworks, they were primarily developed and validated in industrialized contexts with stable infrastructures and high digital maturity.



In contrast, agricultural systems in emerging economies are characterized by structural constraints such as limited access to digital infrastructure, low levels of digital literacy, financial constraints, and fragmented land ownership structures. These contextual factors significantly shape technology adoption behaviors.

Feder, Just, and Zilberman (1985) highlight that agricultural technology adoption is strongly influenced by risk, uncertainty, and access to information, which are often underrepresented in dominant IS models. Consequently, applying TAM, UTAUT, TOE, or DOI without contextual adaptation may lead to incomplete or biased interpretations of adoption behavior in agricultural settings.

Consequently, the direct transposition of mainstream IS adoption theories to agricultural settings in developing countries should be approached with caution. While TAM, UTAUT, and TOE provide valuable explanatory mechanisms, they were not originally designed to account for the structural constraints, risk perceptions, and socio-economic conditions characterizing many agricultural systems in emerging economies. This suggests that Green IT adoption in agriculture should be analyzed through a contextualized perspective that combines established IS theories with agriculture-specific determinants highlighted in the agricultural innovation literature.

## **2.5. Bibliometric studies on agricultural digitalization and their limitations**

Recent bibliometric studies have contributed to mapping the evolution of digital agriculture research. Bertoglio et al. (2021) examine smart agriculture technologies and highlight thematic evolution in precision farming and data-driven agriculture. Similarly, Luckyardi et al. (2022) analyze digital transformation trends in agriculture, focusing on technological convergence and innovation diffusion.

Although these studies provide valuable insights into the structure and evolution of the field, they remain primarily technology oriented. In particular, they do not explicitly integrate Green IT as a conceptual bridge between environmental sustainability and information systems management in agricultural contexts. Moreover, behavioral dimensions such as adoption, acceptance, and actual use are only marginally addressed in these bibliometric syntheses.

In contrast to these existing bibliometric reviews, which mainly emphasize technological and thematic mappings, there is still limited work that positions Green IT within the broader intellectual structure of agricultural digital transformation research.

## **2.6. Research gap and theoretical positioning**

Based on the reviewed literature, three main gaps can be identified. First, the field remains conceptually fragmented across overlapping labels such as smart agriculture, precision agriculture, and digital agriculture, with limited theoretical integration under the Green IT perspective. Second, dominant IS adoption theories are often applied in isolation, without critical synthesis or contextual adaptation to agricultural systems, particularly in emerging economies. Third, behavioral constructs related to adoption, acceptance, and actual use are frequently conflated, limiting a comprehensive understanding of the technology lifecycle.

To address these gaps, this study proposes a bibliometric and conceptual analysis of Green IT in agriculture. It aims to map the intellectual structure of the field and clarify its theoretical foundations across technological, organizational, environmental, and behavioral dimensions.

## **3. Methodology**

This study adopts a bibliometric analysis approach based on the four-step framework proposed by Donthu et al. (2021), ensuring a systematic, transparent, and reproducible research design. The methodological workflow is presented in Figure 1.

To ensure a comprehensive understanding of the field, this study employs a multi-method bibliometric approach combining keyword co-occurrence analysis and author co-citation analysis. This dual approach enables the exploration of both the conceptual structure of digital agriculture research and its underlying intellectual foundations.

Importantly, this study does not treat Green Information Systems (Green IT) as a keyword for data retrieval, but rather as an interpretive analytical lens used to examine sustainability-oriented dimensions emerging within the broader literature on digital agriculture and technology adoption.

### **3.1. Data source and selection**

The scope of the analysis is defined around digital agriculture and technology adoption research, including related domains such as precision agriculture, smart agriculture, and agricultural digital transformation.

Bibliographic data were retrieved from the Scopus database, selected due to its extensive coverage of peer-reviewed journals and conference proceedings in information systems, management, engineering, and agricultural sciences.

Compared to Web of Science, Scopus provides broader multidisciplinary coverage, particularly for applied and interdisciplinary research fields. Prior comparative studies confirm that Scopus includes a wider range of journals and conference proceedings in technology and applied sciences, making it particularly suitable for bibliometric research in emerging domains (Mongeon & Paul-Hus, 2016; Falagas et al., 2008; Aghaei Chadegani et al., 2013).

Although Scopus offers extensive coverage, the use of a single database may introduce potential coverage bias, which is acknowledged as a limitation of this study.

### **3.2. Selection of analytical techniques**

The bibliometric analysis was conducted using VOSviewer software, a widely used tool for constructing and visualizing bibliometric networks. The study primarily employs keyword co-occurrence analysis to identify the conceptual structure of the field. This technique examines the frequency with which two keywords appear together within the same documents, thereby revealing patterns of conceptual association and thematic proximity across the literature.

A full counting approach was applied to ensure that each keyword occurrence contributes equally to the analysis. Network visualization is based on a distance-based layout, where the proximity between nodes reflects the strength of their co-occurrence relationships. The Total Link Strength (TLS) indicator is used to measure the overall strength of connections between keywords, allowing the identification of highly interconnected thematic areas within the field. To ensure robustness and provide a complementary perspective on the intellectual structure of the field, an author co-citation analysis is also performed. This method identifies authors who are frequently cited together, thereby capturing the underlying theoretical and intellectual foundations of the research domain. The combination of keyword co-occurrence and co-citation analysis allows for a dual-level mapping of the field, covering both its conceptual structure and its intellectual base, which is particularly relevant for understanding interdisciplinary domains such as digital agriculture and sustainability-oriented information systems.

### **3.3. Data collection**

The final search query used for data retrieval was:

("Adoption" OR "Acceptance" OR "Use") AND ("Precision agriculture" OR "smart agriculture" OR "green agricultural technologies")

This query was designed to capture research at the intersection of technology adoption and digital agriculture systems. Adoption-related terms ensure inclusion of behavioral and

managerial dimensions of technology use, while agriculture-related terms ensure relevance to digital transformation in agricultural contexts.

The term “Green IT” is not consistently used in agricultural bibliographic databases. Therefore, sustainability-related concepts are captured through related terminology such as “green agricultural technologies”. Green Information Systems is not used as a retrieval criterion but is applied as an interpretive framework during analysis.

A PRISMA-based screening process was applied to ensure transparency and reproducibility of the dataset selection process. The initial dataset consisted of 7,365 documents, which was reduced to 5,984 records after applying inclusion and exclusion criteria. These criteria included relevance to agricultural digital technologies, document type filtering (articles and conference papers), and thematic alignment with technology adoption and digital agriculture research. The full screening process is presented in Figure 2.

### 3.4. Data analysis and reporting of findings

The bibliometric analyses were conducted using VOSviewer software, a widely used tool for constructing and visualizing bibliometric networks.

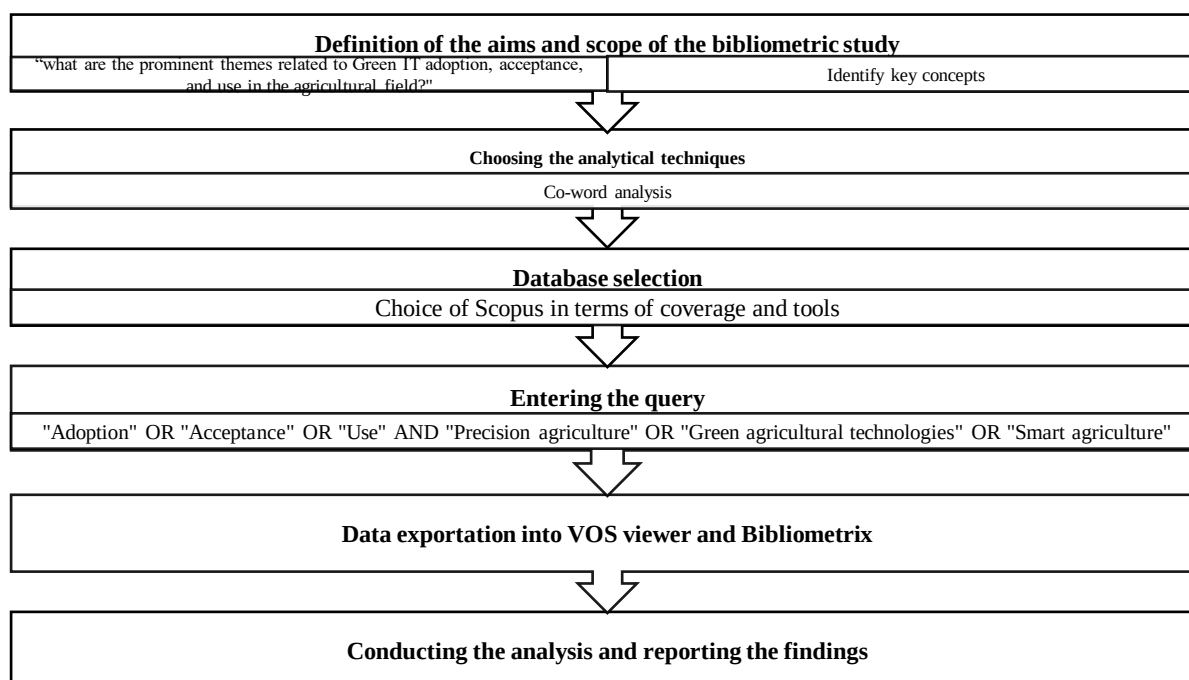
#### 3.4.1. Keyword co-occurrence analysis

Keyword co-occurrence analysis was used to identify the conceptual structure of the field by examining the frequency with which keywords co-occur within the same documents. This method reveals patterns of thematic association and intellectual proximity across the literature. A full counting method was applied. To ensure analytical robustness and reduce noise from low-frequency terms, only keywords with a minimum occurrence threshold of five ( $\geq 5$ ) were included in the analysis.

Network visualization is based on a distance-based layout in which the proximity between nodes reflects the strength of co-occurrence relationships. The Total Link Strength (TLS) indicator is used to measure the overall strength of connections between keywords, enabling the identification of highly interconnected thematic clusters.

#### 3.4.2. Author co-citation analysis

*Figure 2: Authors 'research design*



Source: Authors



To complement the conceptual mapping, an author co-citation analysis was conducted. This method identifies authors who are frequently cited together, revealing the intellectual and theoretical foundations of the field.

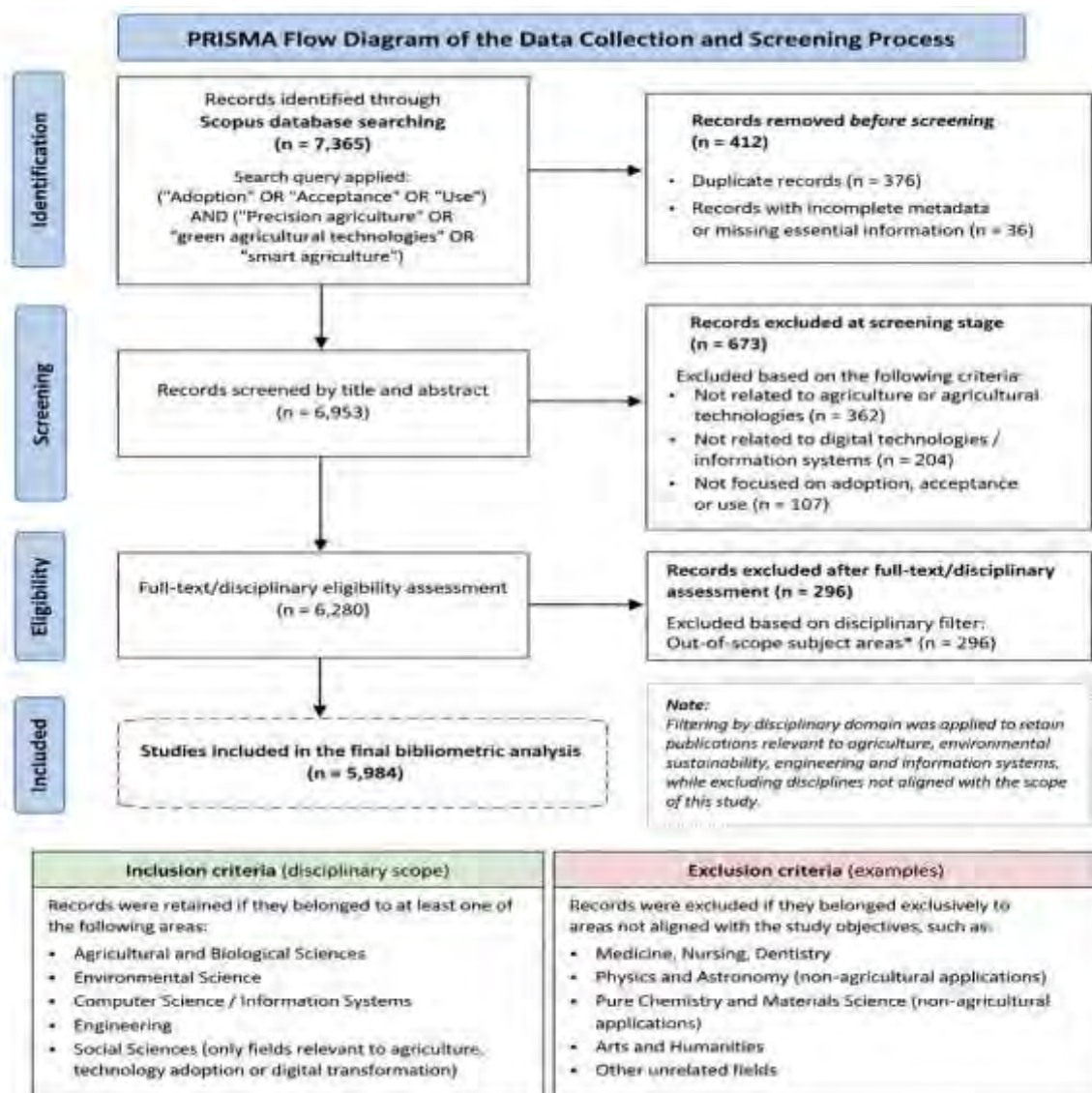
The combination of keyword co-occurrence and author co-citation analysis enables a dual-level understanding of the field, capturing both its conceptual structure and intellectual foundations. This is particularly relevant for interdisciplinary domains such as digital agriculture, where technological, behavioral, and sustainability perspectives intersect.

The final dataset was exported to VOSviewer for bibliometric analysis. Keyword co-occurrence analysis was used to identify thematic clusters, while author co-citation analysis was used to uncover intellectual foundations.

The integration of these two complementary methods provides a robust analytical framework for mapping both the conceptual and intellectual structure of digital agriculture research.

The results are presented in the following section, highlighting major thematic clusters, intellectual influences, and emerging research trends in digital agriculture from a sustainability-oriented perspective.

**Figure 3 : PRISMA Flow diagram of the data collection**



*Note: Numbers may not sum exactly due to rounding and the dynamic nature of the Scopus database.*

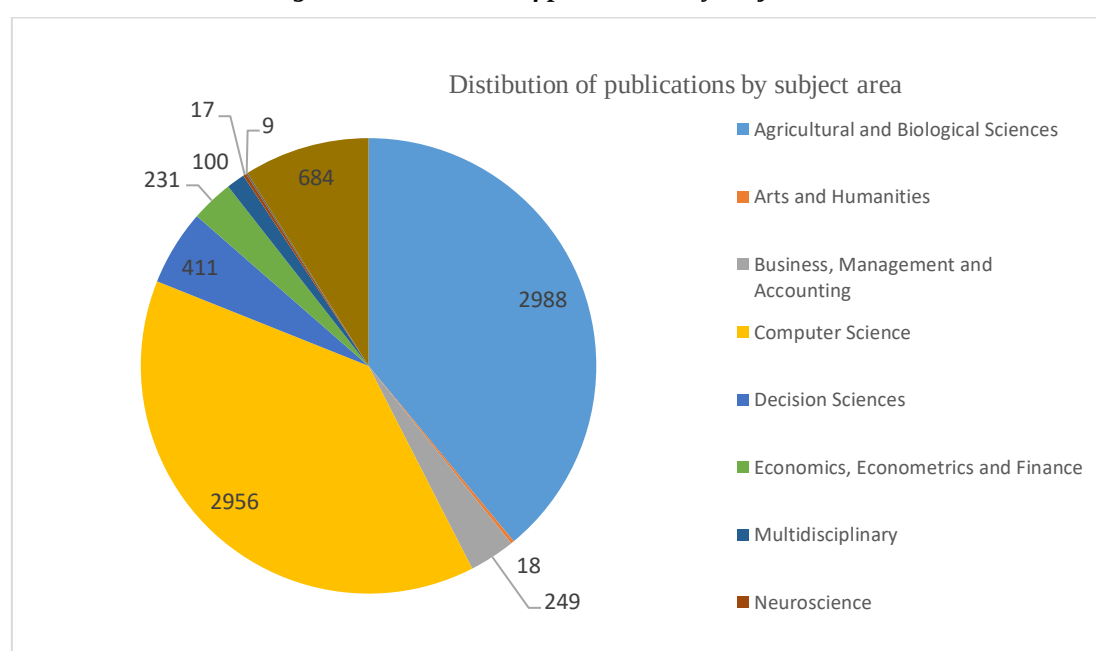
Source: Authors

## 4. Results

Following the application of the bibliometric search strategy described in the methodology section, a total of 7,365 documents were initially retrieved from the Scopus database. After applying the inclusion and exclusion criteria, 5,984 publications were retained for further analysis. This dataset constitutes the final corpus used for the bibliometric mapping of Green IT and digital agriculture research.

Figure 4 presents the distribution of publications by subject area. The results indicate a strong dominance of Agricultural and Biological Sciences (2,988 documents) and Computer Science (2,956 documents), highlighting the technological and agronomic foundations of the field. Social Sciences (684 documents) also represent a significant share, reflecting the importance of behavioral, organizational, and policy-related dimensions in technology adoption. Other disciplines, such as Psychology, Neuroscience, and Arts and Humanities, remain marginal but indicate the interdisciplinary expansion of the research domain.

**Figure 4: Distribution of publications by subject area**



**Source: Authors**

### 4.1. Keyword co-occurrence

A keyword co-occurrence analysis was conducted using VOSviewer to identify the conceptual structure of the field. The analysis is based on 2,472 keywords occurring at least five times in the dataset. The minimum occurrence threshold of five was selected to ensure a balance between network stability and thematic inclusiveness, avoiding excessive noise from highly specific or marginal terms while preserving emerging but relevant research topics.

The resulting network is organized into four major clusters, each representing a distinct thematic dimension of Green IT and digital agriculture research. The Total Link Strength (TLS) indicator is used to assess the strength of relationships between keywords and to identify the most influential conceptual nodes (Figure 5).

Cluster 1 largely dominates the network, comprising 986 keywords, whereas Cluster 2 contains only four keywords and Cluster 3 only two. This uneven distribution highlights the strong concentration of research around digital and precision agriculture themes, while theoretical and infrastructural topics remain more specialized research streams.

#### 4.1.1. Cluster 1 : Digital agriculture and smart farming systems

The strong interconnections among these keywords indicate a high level of conceptual integration around data-driven farming systems, sensor technologies, automation, and digital decision-support tools. In particular, “precision agriculture” appears as the main conceptual anchor of the network, suggesting that most research streams originate from or converge toward this theme. The close association between “IoT”, “smart farming”, and “smart agriculture” further reflects the growing convergence between information technologies and agricultural production systems.

#### 4.1.2. Cluster 2 : Theoretical and behavioral foundations of technology adoption

Among these terms, “intention” emerges as one of the most influential nodes, with 3 occurrences and a Total Link Strength (TLS) of 7. This finding confirms its widespread use as the principal explanatory construct in studies examining farmers’ adoption decisions. Similarly,

“DOI” exhibits comparable occurrence and connectivity levels, highlighting the continued relevance of innovation diffusion theory in explaining the acceptance of digital and sustainable agricultural technologies.

The strong association between DOI, intention, and SEM suggests a highly integrated research stream combining behavioral theories with quantitative modelling approaches. Structural equation modelling is frequently employed to test causal relationships among adoption determinants, further reinforcing the methodological coherence of this cluster. In contrast, “climate change adaptation” displays lower connectivity (Occurrences = 2; Total Link Strength = 5), indicating that environmental resilience remains a more specialized but increasingly important dimension of technology adoption research. Overall, this cluster reflects the intersection of behavioral theories, methodological approaches, and sustainability concerns.

#### **4.1.3. Cluster 3 : Information systems and IoT infrastructure**

The third cluster is composed of two strongly interconnected keywords: “information model” and “IoT platform”. Both terms exhibit two occurrences and a Total Link Strength of 4, indicating a specialized but cohesive research stream focused on the technological infrastructure supporting smart agriculture systems.

The close relationship between these keywords highlights the importance of information modelling, interoperability, and real-time data processing in enabling IoT-based agricultural applications. This cluster emphasizes the foundational role of digital infrastructures in collecting, integrating, and transforming agricultural data into actionable information. Although smaller than the previous clusters, it serves as an important intermediary layer linking technological infrastructures with practical smart farming applications.

#### **4.1.4. Cluster 4 : Organizational and affective dimensions**

The fourth cluster is represented by more isolated but conceptually meaningful keywords, including “information systems and technology management” and “affect”. Compared with the previous clusters, this group exhibits weaker connectivity and a lower level of thematic consolidation, suggesting that research on organizational and psychological dimensions remains relatively underdeveloped within the field.

Nevertheless, the presence of these keywords indicates emerging research interests extending beyond technological and behavioral explanations of adoption. In particular, the inclusion of “affect” highlights the growing recognition of emotional and psychological factors that may influence farmers’ perceptions and acceptance of digital technologies. Similarly, “information systems and technology management” points to the importance of organizational capabilities and managerial practices in facilitating technological transformation. Although peripheral within the current network structure, these themes may represent promising avenues for future research.

#### **4.1.5. Cross-cluster interpretation**

The network structure reveals strong conceptual interdependencies among the identified clusters. Cluster 1, which dominates the network in terms of size and connectivity, is closely linked to Cluster 2, indicating that technological innovation and behavioral adoption processes are strongly intertwined in the literature. Cluster 3 acts as a bridging component by connecting digital infrastructures with both technological applications and adoption mechanisms. In contrast, Cluster 4 remains more peripheral but introduces organizational and psychological perspectives that complement the predominantly technological and behavioral focus of the field.

Together, these clusters illustrate a multi-layered research landscape where technological, behavioral, infrastructure, and organizational dimensions interact to shape the development and adoption of Green IT in agriculture.



#### 4.1.6. Temporal evolution of keyword co-occurrence (Overlay visualization)

An overlay visualization was performed using VOSviewer to examine the temporal evolution of keyword co-occurrence patterns in the field of Green IT and digital agriculture. The color gradient reflects the average publication year of keywords, ranging from blue (earlier publications) to yellow (more recent developments).

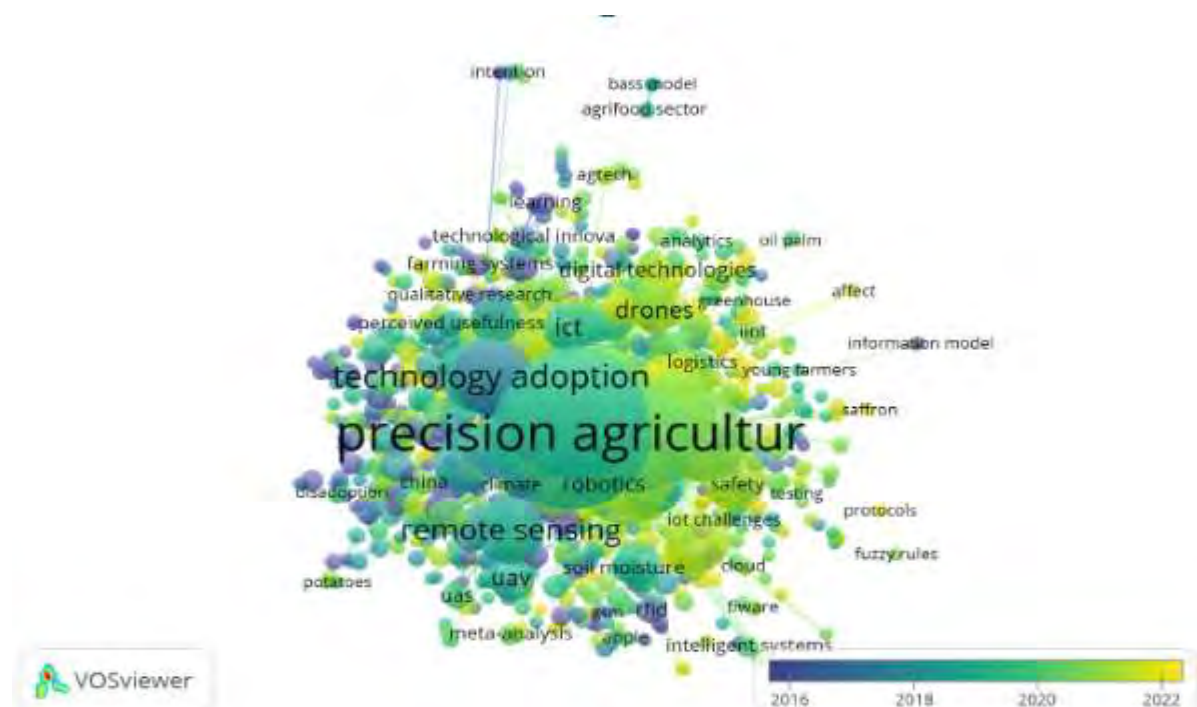
The results reveal a clear temporal structuring of the research field (Figure 6). Early-stage research (blue region, approximately 2016–2018) is primarily centered on foundational concepts such as precision agriculture, early applications of remote sensing, and initial studies on ICT-based agricultural systems. This phase reflects an exploratory stage in which digital technologies were primarily introduced to improve monitoring and productivity in farming systems.

The intermediate phase (green region, approximately 2018–2020) is characterized by the expansion and consolidation of digital agriculture technologies. Keywords such as technology adoption, IoT, sensors, UAVs, and cloud-based systems become more prominent, indicating a shift toward the diffusion and operationalization of smart farming technologies. During this period, literature increasingly integrates technological and behavioral perspectives to understand adoption processes.

The most recent phase (yellow region, approximately 2020–2022) highlights the emergence of advanced and data-intensive approaches, including drones, machine learning, analytics, and intelligent systems. This stage reflects a transition toward AI-driven agriculture, where decision-making processes are increasingly automated and supported by predictive and real-time data analytics. In addition, emerging concerns related to logistics, safety, and system optimization indicate a broader diversification of research applications.

Overall, the overlay visualization demonstrates a clear evolutionary trajectory from precision-based agricultural systems toward intelligent, data-driven, and sustainability-oriented digital agriculture. This confirms the progressive transformation of the field from technology introduction to advanced digital ecosystem integration.

*Figure 6: Overlay Visualization of the keywords' co-occurrence using Vos viewer.*



Source: Authors



## 4.2. Co-citation analysis

To complement the conceptual analysis, an author co-citation analysis was conducted to identify the intellectual structure of the field. This approach highlights authors who are frequently cited together, thereby revealing the foundational knowledge base of Green IT and digital agriculture research.

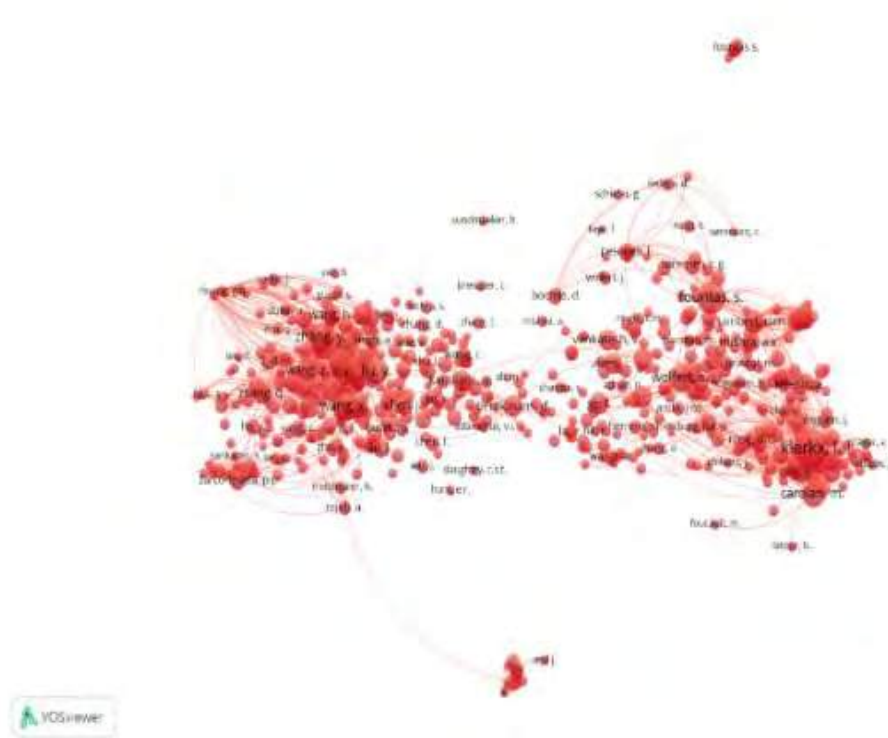
Figure 7 presents the co-authorship network generated using VOSviewer. The network reveals a highly interconnected research community characterized by extensive collaboration among scholars. Two major collaboration clusters can be identified, connected through multiple links that indicate active knowledge exchange and joint research efforts across research groups.

Several authors occupy central positions within the network, notably Klerkx, Fountas, and Carolan, whose large nodes and numerous connections suggest a prominent role in shaping the field and facilitating collaboration among researchers. Their centrality is consistent with the bibliometric performance indicators reported earlier, highlighting their scientific influence and productivity.

Although a few peripheral and isolated groups are present, the overall structure of the network demonstrates a strong collaborative culture within the research domain. The dense interconnections among authors suggest that knowledge production in this field is driven by sustained cooperation, interdisciplinary exchanges, and the development of international research partnerships.

These findings indicate a mature and well-established research community focused on digital agriculture, precision agriculture, and the adoption of emerging agricultural technologies.

**Figure 7: Author co-citation network illustrating the intellectual structure of the field using VOSviewer.**



**Source: Authors**

## 4.3. Scientific performance indicators

To complement the science mapping and network analyses, this section presents standard bibliometric performance indicators, including country-level productivity and collaboration, author productivity, co-citation patterns, and journal impact. These indicators provide a macroscopic view of the intellectual and geographical structure of the field.

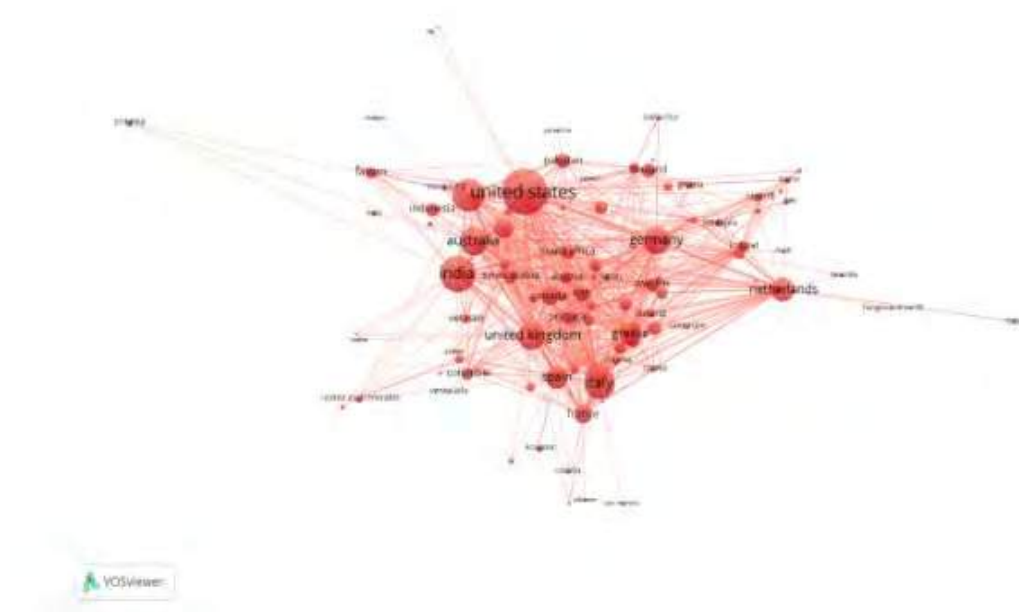
#### 4.3.1. Country-level scientific production and collaboration

The geographical distribution of scientific production reveals a heterogeneous but globally distributed research landscape. The United States represents the most productive country in the dataset, confirming its central role in the development of research on green agricultural technologies adoption.

European countries collectively account for a larger volume of publications compared to Anglo-American countries (USA, UK, Canada, Australia), highlighting the strong contribution of European research institutions to this field. In contrast, African countries remain underrepresented, although South Africa and Ghana emerge as the most productive countries on the continent, with a combined output of 34 publications. Morocco contributes with 6 publications.

The country collaboration network (Figure 8) shows that research in this field is highly collaborative and internationally distributed.

**Figure8: Countries collaboration network using Vos viewer**



**Source: Authors**

#### 4.3.2. Author productivity and collaboration structure

The author collaboration network (Table1) reveals a well-structured co-authorship system composed of seven distinct research communities. This indicates the presence of multiple interconnected but thematically differentiated research clusters within the field.

Table 6 presents the ranking of authors based on scientific productivity and impact. Among the most influential scholars, Dayton Lambert (Oklahoma State University, USA) ranks first with nine publications, along with the highest citation impact indicators (h-index and g-index = 7). Other highly productive authors include English BC, Klerkx L, and Larson JA, each contributing seven publications.

Laurens Klerkx (Wageningen University, Netherlands) is particularly central to the field, with a strong focus on digital agriculture and agrifood innovation. His work, along with other leading scholars, has significantly shaped the theoretical and empirical foundations of smart farming and precision agriculture.

Overall, author productivity is concentrated among a small group of highly influential researchers, while a broader set of authors contributes at a lower but steady level (four publications or fewer among the least productive authors in the top 20).

**Table 1: Ranking of authors based on research productivity generated by R bibliometrix package**

| Auteur       | h-index | g-index | m-index | TC  | NP | Année de début de publication |
|--------------|---------|---------|---------|-----|----|-------------------------------|
| English bc   | 7       | 7       | 0,333   | 174 | 7  | 2002                          |
| Lambert dm   | 7       | 9       | 0,467   | 207 | 9  | 2008                          |
| Larson ja    | 7       | 7       | 0,333   | 215 | 7  | 2002                          |
| Klerkx l     | 6       | 7       | 1,500   | 721 | 7  | 2019                          |
| Roberts rk   | 6       | 6       | 0,286   | 165 | 6  | 2002                          |
| Carolan m    | 5       | 6       | 0,833   | 325 | 6  | 2017                          |
| Musshoff o   | 5       | 5       | 0,333   | 87  | 5  | 2008                          |
| Allahyari ms | 4       | 5       | 0,571   | 151 | 5  | 2016                          |
| Brunori g    | 4       | 4       | 0,444   | 116 | 4  | 2014                          |
| Cavallo e    | 4       | 4       | 0,444   | 172 | 4  | 2014                          |
| Charatsari c | 4       | 5       | 1,000   | 125 | 5  | 2019                          |
| Fountas s    | 4       | 4       | 0,500   | 288 | 4  | 2015                          |
| Jakku e      | 4       | 5       | 1,000   | 519 | 5  | 2019                          |
| Lioutas ed   | 4       | 5       | 1,000   | 125 | 5  | 2019                          |
| Mishra ak    | 4       | 5       | 0,333   | 106 | 5  | 2011                          |
| Wang s       | 4       | 5       | 0,500   | 96  | 5  | 2015                          |
| Ayre m       | 3       | 3       | 0,750   | 240 | 3  | 2019                          |
| Bacco m      | 3       | 3       | 1,500   | 81  | 3  | 2021                          |

TC= Total citations; NP= Number of publications; PY\_start= Year of publication's start

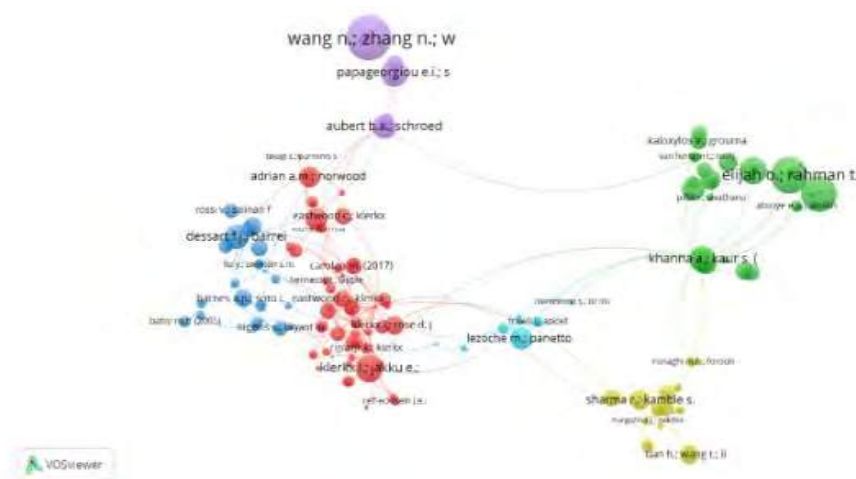
Source: Authors

### 4.3.3. Citation network of documents

The citation network analysis (Figure 9) includes 1,502 documents, of which 214 nodes and 300 links were retained in the largest connected component. Six thematic clusters were identified, reflecting the intellectual structure of the field.

The most cited document is the work by Ning Wang, Naiqian Zhang, and Maohua Wang on wireless sensor technologies in agriculture, published in *Computers and Electronics in Agriculture*, with 845 citations. Other highly influential contributions include Elijah et al. (IoT and data analytics in agriculture, 583 citations) and Ojha et al. (wireless sensor networks, 554 citations), which collectively highlight the technological backbone of smart agriculture research.

**Figure 9: Visualization of citation network analysis of the research field using Vos Viewer.**



Source: Authors

#### 4.3.4. Journal performance analysis

Table 2 presents the 25 most productive journals in the field. The results show a strong concentration of publications in a limited number of core journals.

Sustainability (Switzerland), Computers and Electronics in Agriculture, and Journal of Rural Studies are the most productive outlets, each publishing more than 30 articles. Mid-range journals such as Technology in Society, Sociologia Ruralis, Journal of Cleaner Production, and Land Use Policy contribute between 10 and 20 publications. A second group of journals records fewer than 10 publications, including the International Journal of Sustainable Agricultural Management and Informatics and Technological Forecasting and Social Change.

These results highlight the existence of a core–periphery structure in publication outlets, where a limited number of journals dominate knowledge dissemination in the field.

**Table2 : Top 25 most productive journals in Green agriculture technologies’ adoption**

| Source                                                                             | Articles |
|------------------------------------------------------------------------------------|----------|
| Sustainability (switzerland)                                                       | 53       |
| Computers and electronics in agriculture                                           | 49       |
| Journal of rural studies                                                           | 32       |
| Land use policy                                                                    | 17       |
| Journal of cleaner production                                                      | 16       |
| Njas - wageningen journal of life sciences                                         | 12       |
| Sociologia ruralis                                                                 | 12       |
| Technology in society                                                              | 10       |
| International journal of sustainable agricultural management and informatics       | 9        |
| Technological forecasting and social change                                        | 9        |
| Information processing in agriculture                                              | 8        |
| Journal of agricultural and resource economics                                     | 8        |
| Environment, development and sustainability                                        | 7        |
| Lecture notes in informatics (lni), proceedings – gesellschaft für informatik (gi) | 7        |
| British food journal                                                               | 6        |
| Sensors                                                                            | 6        |
| Acm international conference proceeding series                                     | 5        |
| Agbioforum                                                                         | 5        |
| Agricultural economics (united kingdom)                                            | 5        |
| Applied economic perspectives and policy                                           | 5        |
| Ecological indicators                                                              | 5        |
| Ieee access                                                                        | 5        |
| Agricultural and food economics                                                    | 4        |
| Agris on-line papers in economics and informatics                                  | 4        |
| Ceur workshop proceedings                                                          | 4        |

Source: Authors

## 5. Discussion

### 5.1. Conceptual fragmentation and lack of theoretical consolidation

The findings reveal a strong overlap between dominant terms such as “precision agriculture”, “smart agriculture”, and “smart farming”, reflecting both the rapid expansion and the interdisciplinary nature of the field. This terminological diversity aligns with prior studies that emphasize the absence of a unified conceptual framework in digital agriculture research (Klerkx et al., 2019; Rose & Chilvers, 2018). While such diversity reflects technological progress and multidisciplinary contributions, it also indicates a fragmented and weakly consolidated knowledge structure.

More importantly, the absence of the explicit term “Green IT” among dominant keywords suggests that sustainability-oriented information systems perspectives remain implicit rather

than theoretically established within agricultural research. This observation is consistent with earlier studies showing that sustainability-related digital concepts are often embedded within broader technological narratives without clear conceptual distinction (Bronson & Knezevic, 2016; Eastwood et al., 2019).

In addition, the interchangeable use of “agriculture” and “farming” reinforces semantic ambiguity, which has also been highlighted as a barrier to conceptual convergence in smart farming literature (Klerkx et al., 2019). Overall, the transition from precision agriculture to smart and digital agriculture reflects technological evolution, but prior research also indicates that this progression has not been matched by equivalent theoretical integration (Rose et al., 2021).

Taken together, these findings confirm the need for a more unified conceptual framework integrating Green IT and information systems perspectives into agricultural research.

### **5.2. A predominantly technology-driven research field**

The cluster analysis identifies four dominant thematic areas centered on precision agriculture, remote sensing and artificial intelligence, Internet of Things (IoT), and irrigation systems. This strong technological orientation is consistent with previous bibliometric studies showing that digital agriculture is largely driven by engineering and innovation-oriented perspectives (Eastwood et al., 2019; Klerkx et al., 2019).

Although these technological developments significantly enhance productivity and resource efficiency, they also reveal an imbalance in literature. Prior research similarly emphasizes the underrepresentation of social, organizational, and human dimensions in digital agriculture studies (Bronson & Knezevic, 2016; Rotz et al., 2019).

Key aspects such as governance, user practices, and institutional contexts remain marginal compared to technological optimization.

For instance, IoT and decision support systems are extensively studied from a technical performance perspective, while socio-technical integration processes such as trust, adoption context, and user appropriation remain underexplored (Eastwood et al., 2019). This reinforces the persistence of a techno-centric paradigm, where innovation is primarily understood as a technological rather than socio-technical process.

Overall, the results empirically support earlier calls for more balanced socio-technical approaches in digital agriculture and Green IT research (Rose et al., 2021).

### **5.3. The overlooked role of acceptance and use in Green IT adoption**

A key finding of this study is the limited visibility of “acceptance” and “use” constructs within the bibliometric network. Although “technology adoption” appears in the literature, prior research distinguishes adoption from actual use and post-adoption behavior, which are essential for realizing the full value of agricultural technologies (Michels et al., 2020; Pierpaoli et al., 2013).

Existing agricultural innovation studies show that adoption decisions are shaped by behavioral, economic, and contextual factors, including perceptions, skills, and institutional constraints (Reichardt & Jansen, 2009; Paustian & Theuvsen, 2017). However, these dimensions remain peripheral in the Green IT literature, revealing a gap between technological deployment and behavioral integration.

Moreover, widely used Information Systems frameworks such as TAM and UTAUT remain underrepresented in agricultural studies, despite their strong explanatory power for technology acceptance (Venkatesh et al., 2003). This gap has also been identified in recent research calling for stronger integration between IS theories and agricultural innovation studies (Michels et al., 2020).

Thus, this study provides bibliometric evidence of the marginal position of acceptance and use constructs within the intellectual structure of Green IT in agriculture.



#### **5.4. Toward an integrative research agenda**

Taken together, these findings highlight a persistent misalignment between technological development and the socio-organizational dimensions of digital agriculture. This observation is consistent with recent calls in the literature advocating for more integrative and interdisciplinary approaches to agricultural innovation (Ingram & Maye, 2020; Rose et al., 2021).

Addressing this gap requires moving beyond a purely technology-driven perspective toward a socio-technical systems approach that integrates technological innovation, organizational practices, and human behavior. Such an approach is particularly relevant in contexts characterized by structural constraints and heterogeneous adoption conditions, such as developing countries.

Our study contributes to this emerging agenda by providing empirical bibliometric evidence of these imbalances and by highlighting the need to explicitly integrate Green IT perspectives within agricultural innovation research. This opens new avenues for future research focusing on user-centered, context-specific, and sustainability-oriented digital agriculture systems.

##### **5.4.1. Conceptual consolidation of Green IT in agriculture**

A first important avenue concerns the conceptual clarification of Green IT within agricultural research. The results highlight persistent ambiguity between closely related terms such as precision agriculture, smart farming, and digital agriculture, while Green IT itself remains largely implicit. This raises important questions regarding how these concepts are defined and differentiated across disciplines, and whether a more unified conceptual framework can be developed to structure this emerging field. Addressing this issue requires future research to investigate how Green IT-related concepts are operationalized in both agricultural and information systems literature, and to explore pathways toward theoretical consolidation. Methodologically, this line of research would benefit from systematic literature reviews, bibliometric techniques such as co-word analysis or bibliographic coupling, as well as qualitative synthesis approaches aimed at refining conceptual boundaries.

##### **5.4.2. Behavioral and adoption dynamics**

A second direction relates to the behavioral dimension of Green IT adoption, which appears underdeveloped in the current literature. Although the notion of “technology adoption” is widely used, the results suggest that limited attention is given to actual use and post-adoption behavior. This opens several important research questions, particularly regarding the factors that influence farmers’ intention to adopt and continuously use Green IT technologies, as well as the role of contextual and perceptual determinants in shaping adoption outcomes. Future studies could, for instance, examine how perceived usefulness, ease of use, trust, or perceived risk influence adoption behavior in agricultural settings. From a methodological perspective, survey-based designs using established theoretical models such as TAM or UTAUT, combined with structural equation modeling or regression analysis, appear particularly suitable. These quantitative approaches could be complemented by qualitative case studies in order to capture contextual variability and deepen the understanding of user behavior.

##### **5.4.3. Socio-technical and organizational perspectives**

A third research direction concerns the socio-technical and organizational dimensions of Green IT implementation. The findings indicate that the literature remains largely technology-centric, with insufficient integration of organizational structures, institutional environments, and human factors. This raises important questions regarding how organizational and institutional conditions influence the implementation and performance of Green IT systems, as well as how technological and human dimensions interact in shaping digital transformation processes in

agriculture. To address these issues, future research could adopt multi-method approaches, including comparative case studies, configurational methods such as fuzzy-set Qualitative Comparative Analysis (fsQCA), or multi-level modeling approaches capable of capturing complex interactions between variables.

#### **5.4.4. Sustainability and contextual diversity**

Finally, the analysis highlights the need to further explore sustainability outcomes and contextual diversity, particularly in developing country settings where structural constraints may significantly affect adoption processes. This opens research questions related to the extent to which Green IT contributes to environmental sustainability, resource efficiency, and climate resilience in agriculture, as well as the main institutional and infrastructural barriers that hinder its adoption in developing contexts. Methodologically, this stream of research would benefit from mixed-method designs combining bibliometric insights with empirical field studies, econometric analyses, or cross-country comparative approaches.

Overall, this agenda emphasizes the need to move beyond a purely technology-driven perspective toward a more integrated socio-technical understanding of Green IT in agriculture, combining conceptual clarity, behavioral insights, organizational analysis, and sustainability considerations.

#### **5.5. Implications for agricultural organizations**

The results suggest that agricultural organizations should move beyond a purely technological approach to digital transformation. Rather than focusing solely on technology acquisition, they should adopt data-driven agricultural strategies supported by organizational capabilities in data management, system integration, and cross-disciplinary collaboration.

At the farm level, the findings emphasize that technological success depends not only on availability but also on user capability and appropriation. Strengthening digital literacy and training is therefore essential, particularly for small and medium-sized farms. Cooperative structures can also play a key role in facilitating knowledge sharing and reducing adoption barriers.

From a policy perspective, public authorities should actively support Green IT adoption by addressing financial, infrastructural, and institutional constraints. Investments in rural connectivity, targeted subsidies, and capacity-building programs are essential to bridge the digital divide. Furthermore, digital agriculture strategies should be aligned with sustainability objectives to ensure environmental as well as productivity gains.

Overall, these findings highlight that successful Green IT adoption requires coordinated action across technological, organizational, and policy levels.

##### **5.5.1. Managerial implications for farmers and cooperatives**

At the farm level, the limited visibility of acceptance and use constructs in the literature suggests that technological success depends not only on availability but also on farmers' ability to appropriate and effectively use these systems. Therefore, strengthening digital literacy and technical training among farmers emerges as a key priority.

In addition, adoption strategies should consider the heterogeneity of farming contexts. Simplified and context-adapted technologies are more likely to be effectively adopted, particularly in small and medium-sized farms. Cooperative structures can also play a central role in facilitating knowledge sharing, reducing individual costs of adoption, and promoting collective learning processes.

Furthermore, reducing resistance to change requires continuous support mechanisms, including demonstration projects, pilot implementations, and extension services that bridge the gap between technology developers and end users.

### 5.5.2. Policy implications for digital agriculture and Green IT adoption

The findings also have significant implications for public policy, particularly in the context of developing countries where structural constraints remain a major barrier to digital transformation in agriculture. Public authorities should play an active role in reducing financial, infrastructural, and institutional barriers to Green IT adoption.

First, targeted subsidies and financial support mechanisms can facilitate access to digital agricultural technologies, especially for smallholder farmers. Second, investment in rural digital infrastructure, including internet connectivity and data access systems, is essential to enable the effective deployment of smart farming solutions.

In addition, national agricultural policies should integrate digital transformation strategies with sustainability objectives, ensuring that Green IT adoption contributes not only to productivity gains but also to environmental performance improvements.

Finally, in developing countries' contexts, policy interventions should prioritize capacity-building programs and institutional support mechanisms aimed at reducing the digital divide. This includes training programs, extension services, and public-private partnerships designed to accelerate technology diffusion while ensuring local adaptability.

Overall, these implications highlight that the successful implementation of Green IT in agriculture cannot be achieved through technological innovation alone. It requires a coordinated approach involving organizational transformation, managerial capacity building, and supportive public policies. This multi-level perspective reinforces the need to move beyond a purely techno-centric view toward a more integrated socio-technical and policy-oriented framework for agricultural digitalization.

### 5.6. Methodological limitations

Despite the robustness of the bibliometric approach adopted in this study, several methodological limitations should be acknowledged in order to appropriately contextualize the interpretation of the results.

Although an overlay visualization was used to provide an indication of the temporal evolution of keywords, the study does not incorporate a fully longitudinal bibliometric analysis. As a result, the dynamic evolution of research themes over time is only partially captured. A more fine-grained temporal approach, such as time-sliced network analysis, could provide deeper insights into the emergence, growth, and decline of thematic clusters.

The construction of keyword co-occurrence networks relies on the selection of minimum occurrence thresholds, which directly influence the inclusion or exclusion of terms in the analysis. These methodological choices may affect the resulting network structure and the composition of clusters. Consequently, different threshold settings could lead to variations in the interpretation of thematic structures, even when analyzing the same dataset. This study relies exclusively on the Scopus database for data extraction. Although Scopus is widely recognized as one of the most comprehensive bibliographic sources, its coverage may introduce certain biases. In particular, it may underrepresent regional journals, non-English publications, or emerging research outlets not indexed in Scopus. As a result, the findings may reflect a partial representation of the global research landscape on Green IT in agriculture.

This study primarily focuses on conceptual and thematic structures rather than on geographical or institutional patterns of scientific production. As a result, the contribution of specific countries, institutions, or research systems is not systematically analyzed. This limits the ability to fully understand the geographical distribution and institutional concentration of research in Green IT in agriculture.

The use of author keywords as the basis for co-occurrence analysis may introduce terminological bias. Different research communities may use distinct terms to refer to similar

concepts (e.g., smart farming, precision agriculture, digital agriculture), which can affect clustering outcomes. This disciplinary heterogeneity may therefore influence the representation of conceptual proximity within the network.

The methodological framework adopted in this study is primarily cross-sectional and static, focusing on the structure of the field at a given point in time. Although the overlay visualization provides partial insights into temporal evolution, it does not fully capture the dynamic development of research themes over time. Longitudinal approaches or dynamic network analyses could offer deeper insights into the evolution of conceptual structures and research trajectories.

These methodological limitations do not invalidate the findings of the study; however, they suggest that the results should be interpreted as a structural approximation of the field rather than an exhaustive representation. Future research could address these limitations by integrating multiple databases, applying alternative clustering thresholds, and adopting longitudinal bibliometric approaches to capture the dynamic evolution of the field.

## **6. Conclusion**

This study provides a comprehensive bibliometric overview of Green IT research in agriculture by mapping its intellectual structure, thematic evolution, and scientific development. Based on a corpus of 5,984 Scopus-indexed publications and the application of VOSviewer-based science mapping techniques, the findings reveal a rapidly expanding research field driven primarily by technological innovation. The literature is largely organized around themes such as precision agriculture, smart farming, Internet of Things (IoT), artificial intelligence, and digital decision-support systems, reflecting the increasing digitalization of agricultural production systems.

Beyond identifying dominant technological themes, the study highlights several structural characteristics of the field. The results reveal a fragmented conceptual landscape characterized by the coexistence of multiple overlapping concepts, including precision agriculture, smart agriculture, and digital agriculture, while the notion of Green IT itself remains relatively implicit. Furthermore, the analysis points to a persistent imbalance between technological development and the socio-technical dimensions of innovation, with issues related to user behavior, organizational capabilities, and post-adoption use receiving comparatively limited attention.

From a theoretical perspective, this study contributes to the literature by demonstrating the limited integration of Green IT and Information Systems perspectives within agricultural technology research. By identifying conceptual fragmentation and the marginal position of adoption and use constructs, the study highlights the need for stronger theoretical consolidation and greater integration of socio-technical approaches in the study of digital agriculture. These findings contribute to a more comprehensive understanding of how technological innovation, human behavior, and sustainability considerations interact within agricultural systems.

Methodologically, this study contributes by combining multiple bibliometric techniques, including keyword co-occurrence analysis, overlay visualization, co-citation analysis, and scientific performance indicators. This multi-dimensional approach provides a systematic mapping of the field and enables the identification of dominant themes, intellectual foundations, temporal developments, and emerging research directions. The study therefore offers a structured framework that may support future bibliometric investigations in digital agriculture and related sustainability-oriented research domains.

From a practical perspective, the findings suggest that the successful implementation of Green IT in agriculture depends not only on technological advancement but also on organizational readiness, user capabilities, and supportive institutional environments. For agricultural organizations, this highlights the importance of investing in digital skills, training programs, and knowledge-sharing mechanisms. For policymakers, particularly in developing countries,

the results emphasize the need to strengthen rural digital infrastructure, facilitate access to technological resources, and design policies that align digital transformation with sustainability objectives.

Despite these contributions, several limitations should be acknowledged. First, the study relies exclusively on the Scopus database, which may not fully capture publications indexed in other bibliographic sources or regional outlets. Second, the structure of the keyword network is influenced by methodological choices such as the minimum occurrence threshold applied during co-occurrence analysis. Third, the reliance on author keywords may introduce terminological biases, particularly in a field characterized by overlapping concepts and disciplinary diversity. Finally, although overlay visualization provided insights into temporal evolution, the analysis remains predominantly cross-sectional and does not fully capture the dynamic evolution of research themes over time. Future studies could address these limitations by integrating multiple databases, applying longitudinal bibliometric techniques, conducting institution-level analyses, and combining bibliometric methods with systematic literature reviews and empirical investigations.

Overall, this study demonstrates that Green IT research in agriculture is evolving toward a more mature and interdisciplinary domain. However, achieving greater theoretical coherence and practical relevance will require moving beyond a predominantly technology-centered perspective toward a more integrated socio-technical understanding of agricultural digitalization, one that explicitly considers technological innovation, human behavior, organizational dynamics, and sustainability imperatives.

Looking forward, future research should focus on developing more integrated socio-technical frameworks capable of capturing the complex interactions between technological innovation, organizational capabilities, user behavior, and sustainability outcomes. Particular attention should be given to developing country contexts, where institutional constraints, digital infrastructure gaps, and heterogeneous farming conditions may significantly influence Green IT adoption. In addition, longitudinal studies examining the evolution of adoption processes over time, as well as comparative cross-country analyses, could provide valuable insights into the mechanisms through which digital technologies contribute to sustainable agricultural transformation. Such efforts would help advance the field from a predominantly technology-oriented perspective toward a more comprehensive understanding of sustainable digital innovation in agriculture.

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